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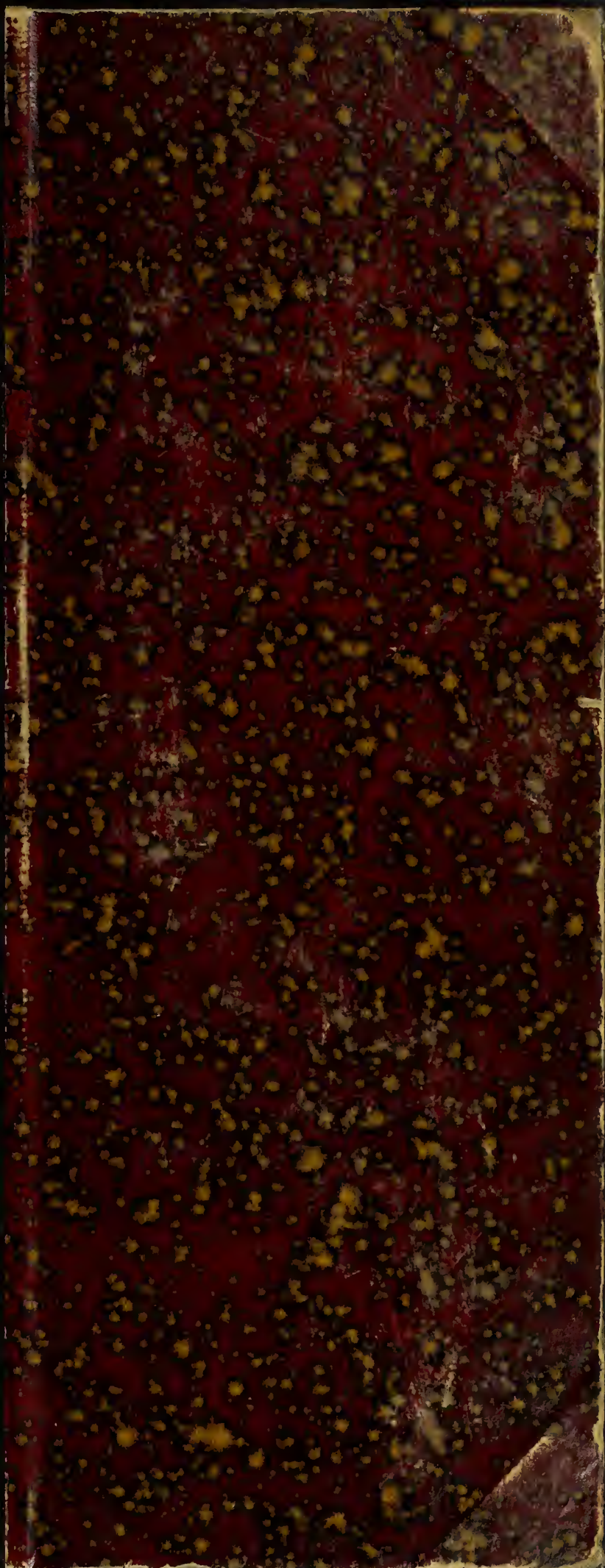
A Study of Direct
and Indirect Illumination

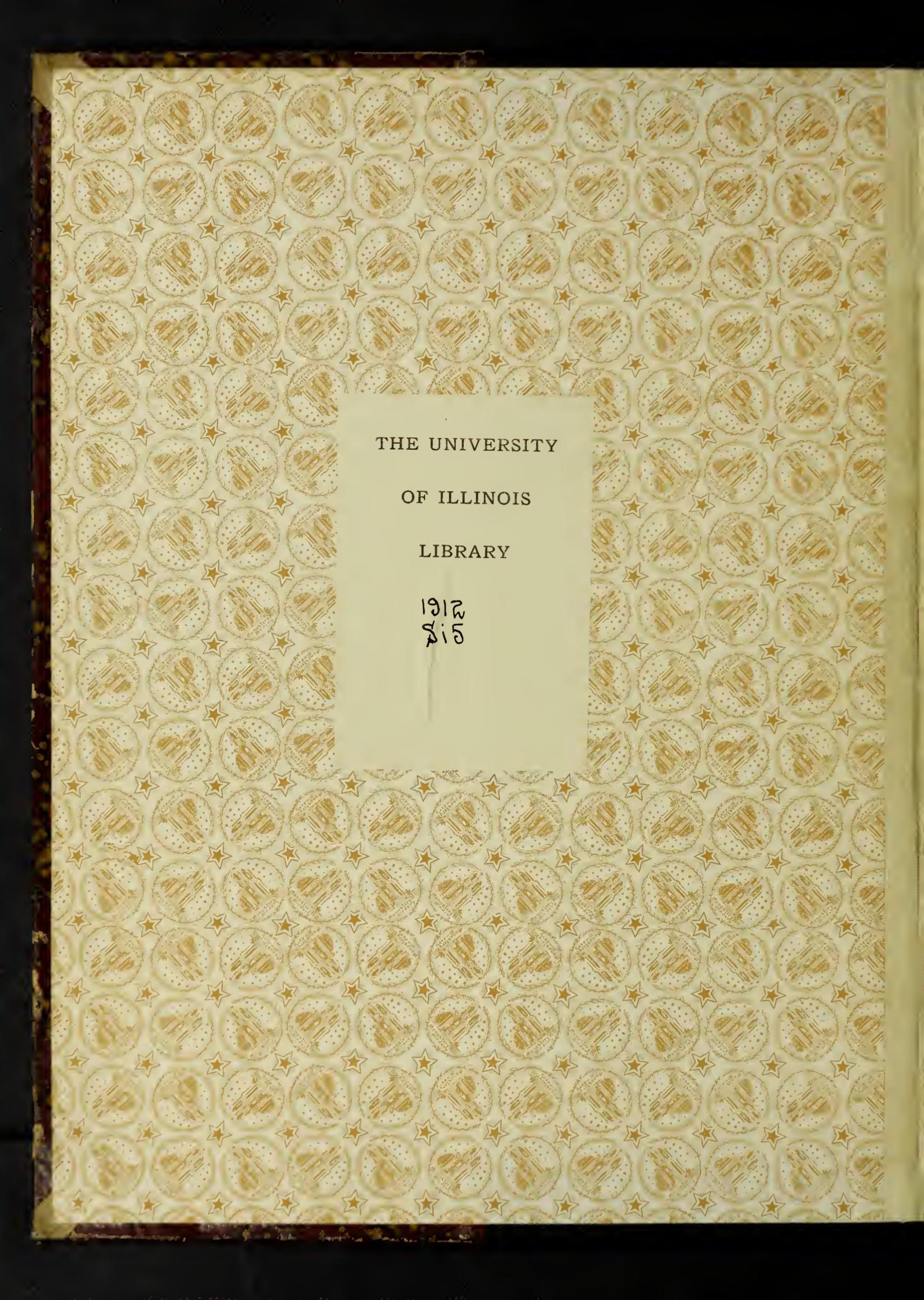
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A STUDY OF DIRECT AND INDIRECT ILLUMINATION

BY

ALEXANDER McDOUGALL SIMONS

THE S I S

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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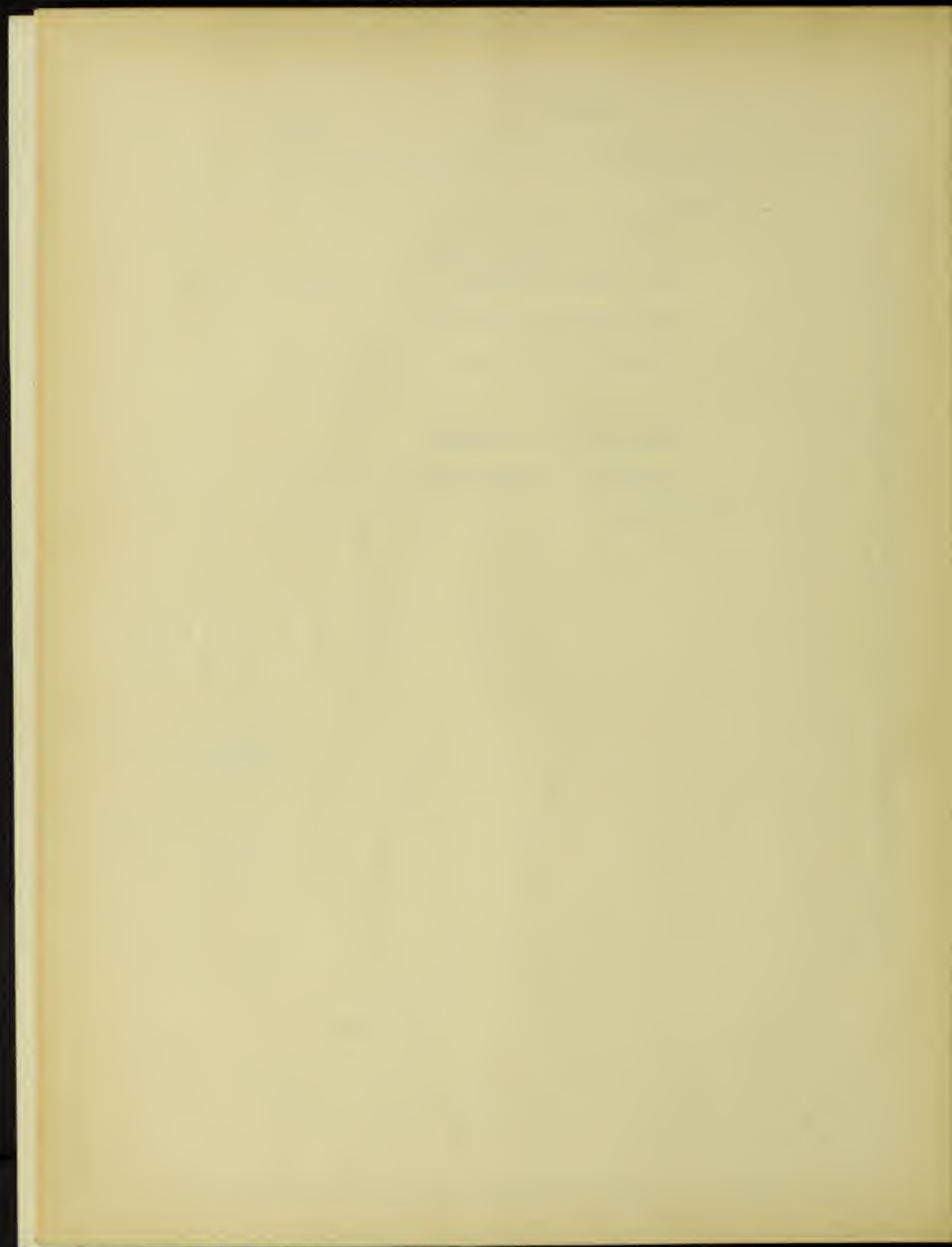
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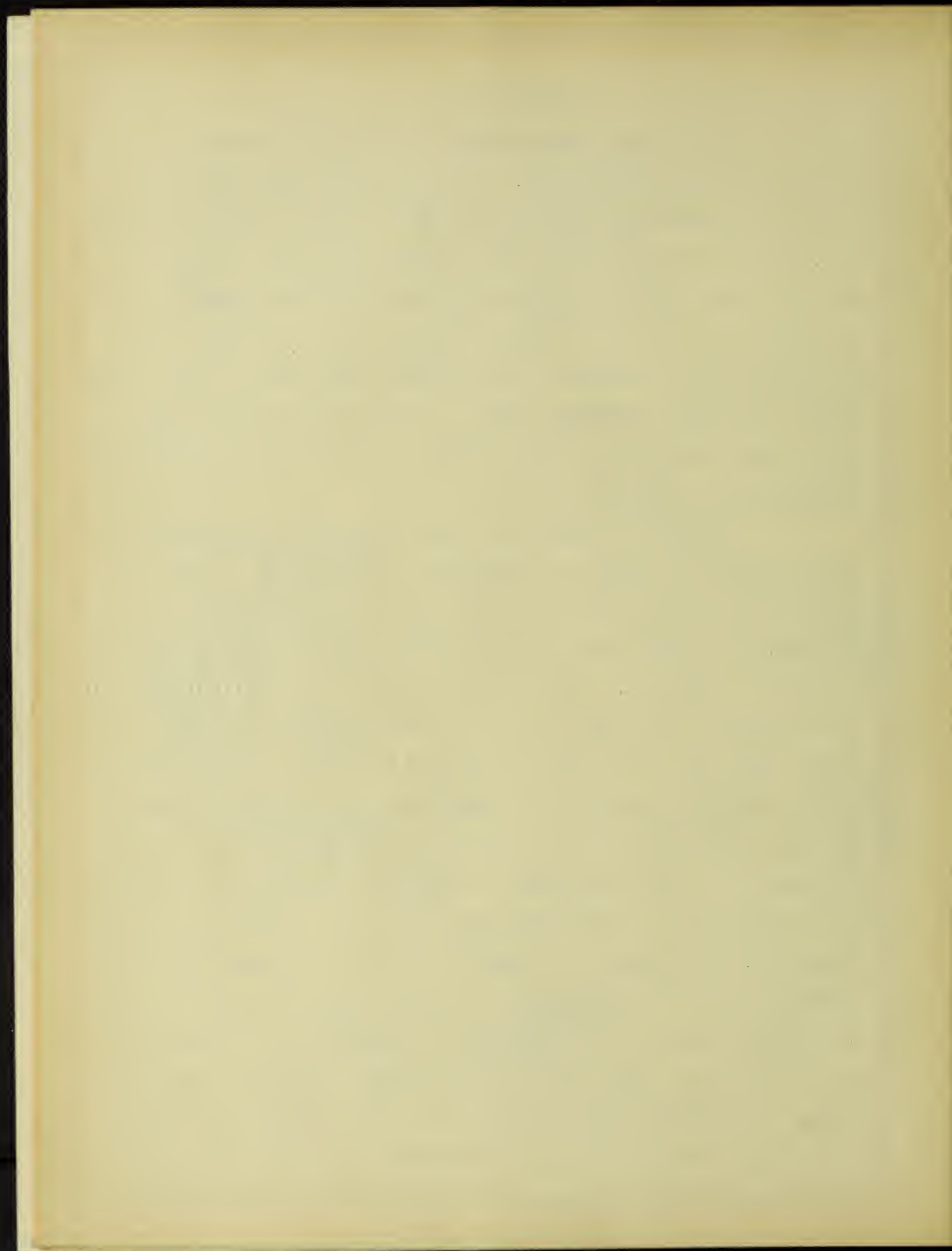
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INTRODUCTION.

In the early times torches were the only source of artificial illumination known. It was not until about 1400 that a means of separating tallow was invented, and the candle came into use. After this until 1855, about 20 years after the discovery of coal gas, very little progress was made in the development of artificial illumination. Then gas began to come into use. In 1860 petroleum was discovered and the kerosine lamp came into use. About thirty years ago electricity began to replace the kerosine lamp, until today except in isolated places, the chief sources of artificial light are electricity and gas.

In order to compare different systems of illumination there must be some means of comparison. Consequently we have the candle power, foot candle, mean spherical candle power(M.S.C.P.), and etc. The candle power is the unit by which the intensity of a source is measured. Thus a light is said to have an intensity of one candle power when it has the same intensity as a sperm candle which burns 20 grams of sperm in 10 minutes. This is the English unit of intensity. The German unit is .9 of the English one, while the French unit is 9.64 times the English one. As the intensity of a source may vary in different directions, the average intensity is often of more importance than the intensity in any one direction. Consequently, we speak of the mean spherical candle power (M.S.C.P.) of a source, meaning the average intensity of the said source. Thus if it is said that a source has an intensity of one M.S.C.P., it would mean that the average intensity of that source is one candle power. However, in order to find the amount of light in any one point, it is necessary to know the distance



that the point is from the source as well as the intensity of the source. Consequently, another unit has been devised namely, the foot candle. A footcandle is the amount of light received on a point in a plane perpendicular to the ray of light at a distance of one foot from the source of light whose intensity is one candle power.

As light is given off in all directions, the amount of light received on any surface will vary inversely as the square of the distance from the source. Also it is evident that the amount of light will depend directly upon the intensity of the source. Thus if E represents the normal illumination at any point, I , the intensity of the source, and D , the distance from the point to be considered, $E \propto I/D^2$ or $E = k \times I/D^2$. If E is measured in foot candles, I , in candle power, and D , in feet, The constant k will equal one and, consequently, disappear. Then $E = I/D^2$.

But it is very seldom that the normal illumination at any point is wanted, usually, the horizontal illumination or even the vertical illumination being wanted.

Now from Fig. 1 it is evident that the illumination on a horizontal plane (E_h) will be the product of the intensity of the source divided

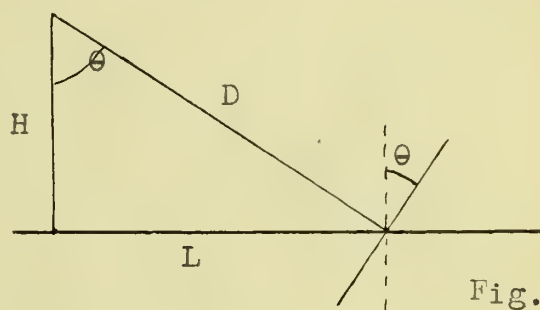
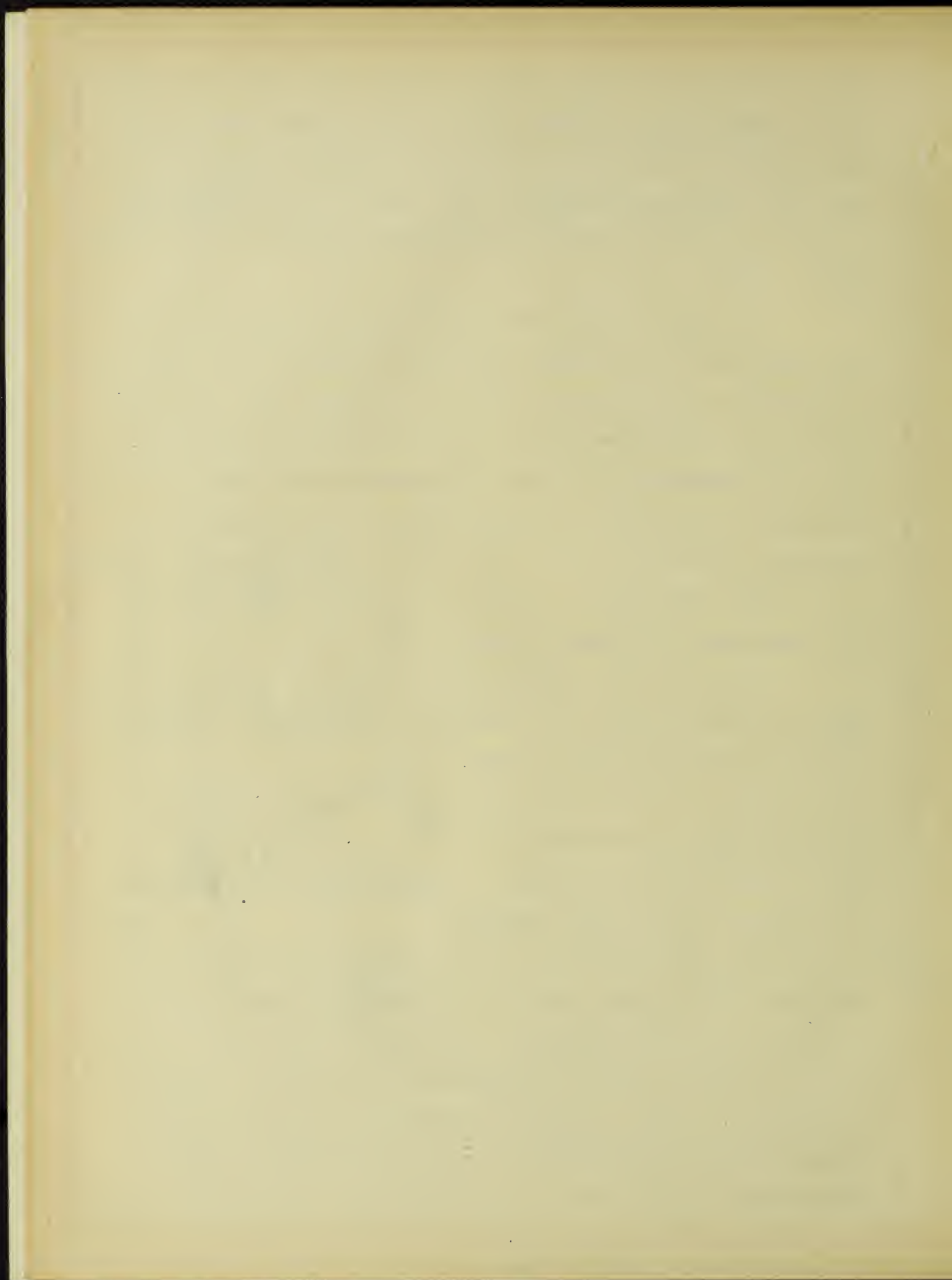


Fig. 1

by the square of the distance from the source to the plane times the cosine of the angle between the vertical and the direction of the ray $E_h = \frac{I}{D^2} \cos \theta$, where θ is the angle between the direction of the ray and the vertical. Similarly the vertical illumination $E_v = \frac{I}{D^2} \sin \theta$. In Fig. 1 let H be the distance of the light above the plane of illumination and L the distance along the plane of illumination from the foot of the perpendicular through the source



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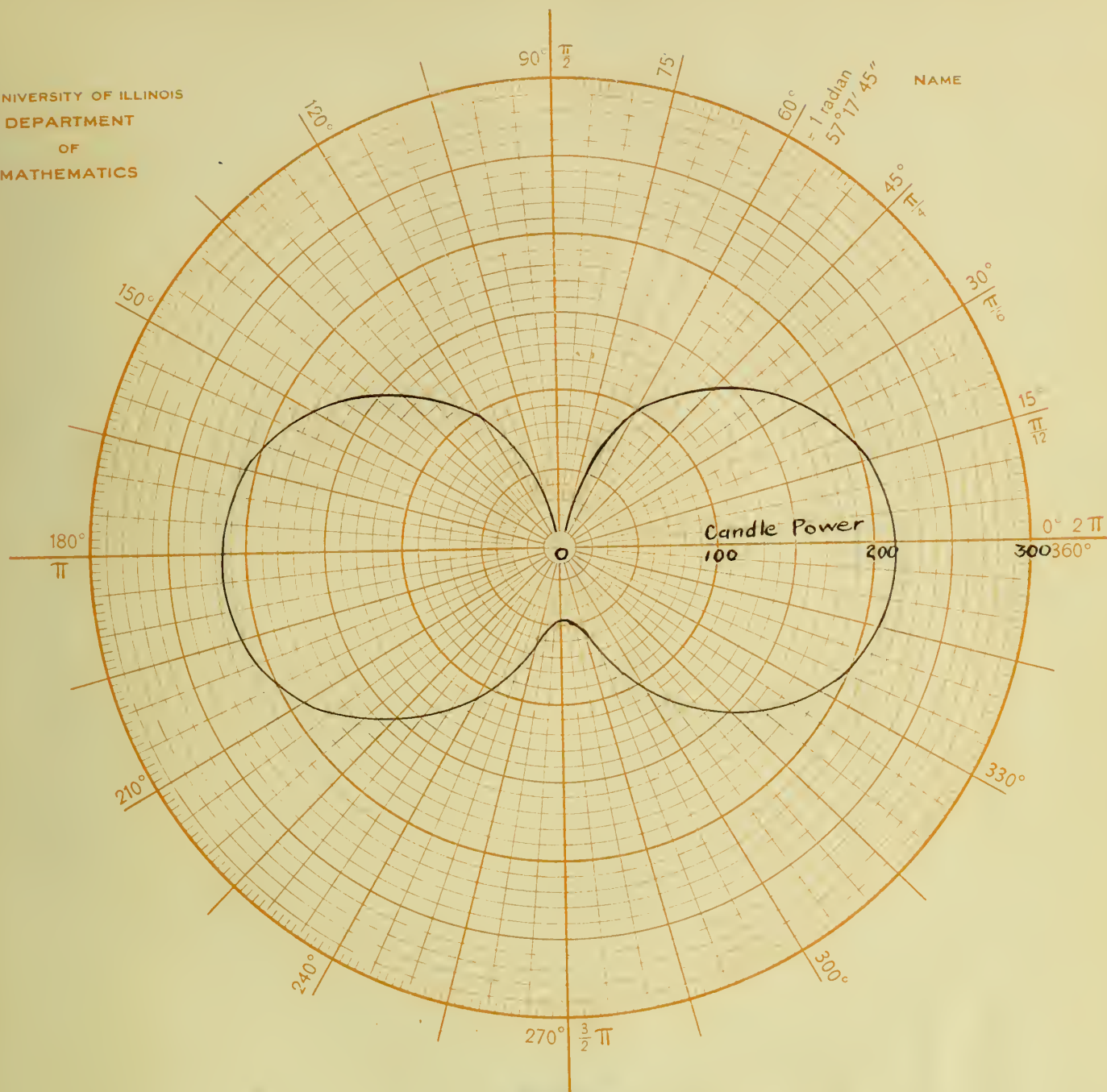


Fig. 2.

Distribution of light in a vertical plane around a
200 candle power (250 watt) series tungsten lamp.



A diagram illustrating the construction of a circle tangent to a given circle and a line.

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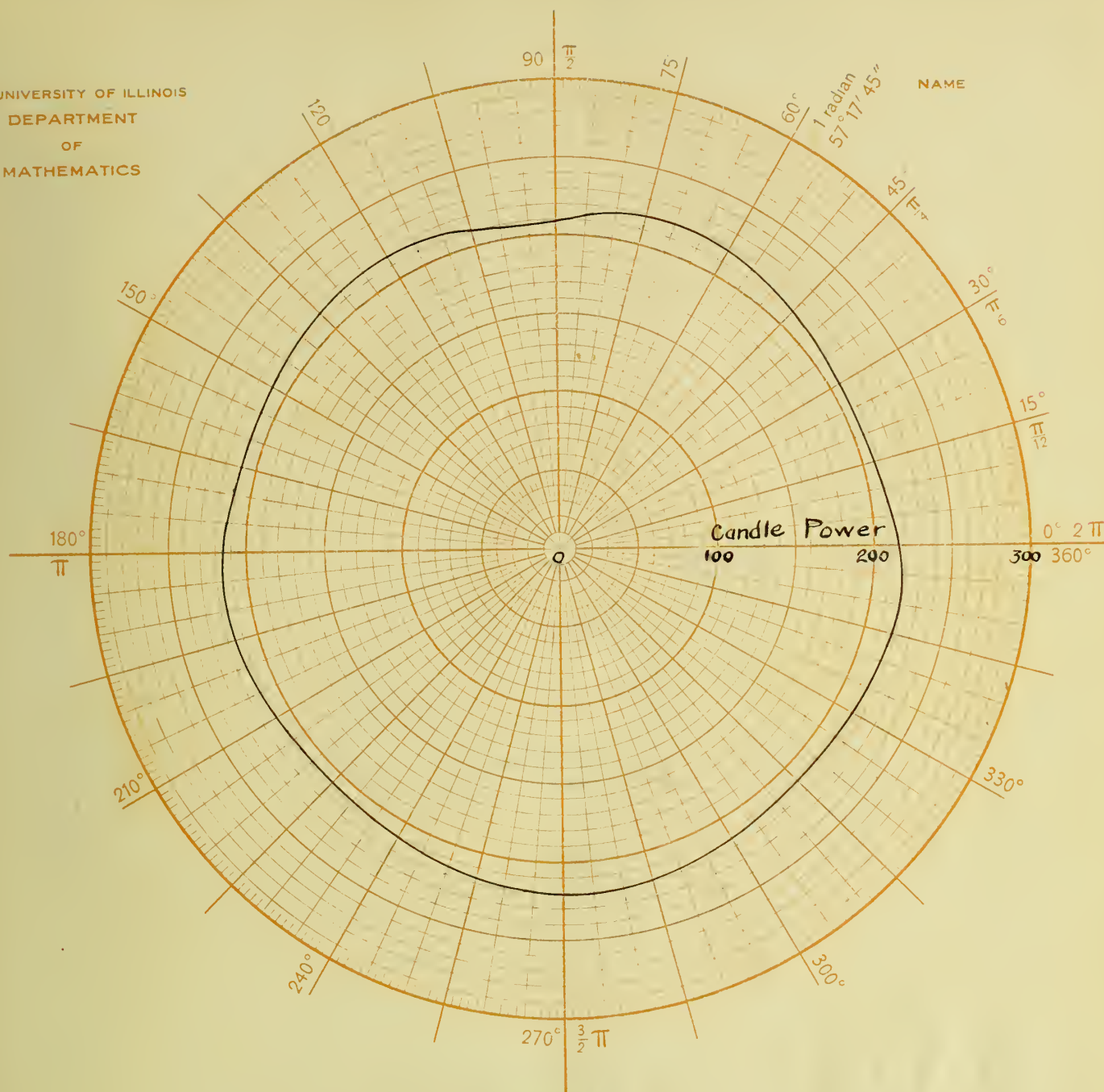


Fig. 3

Distribution of light in a horizontal plane
around a 200 candle power (250 watt) series tungsten
lamp.



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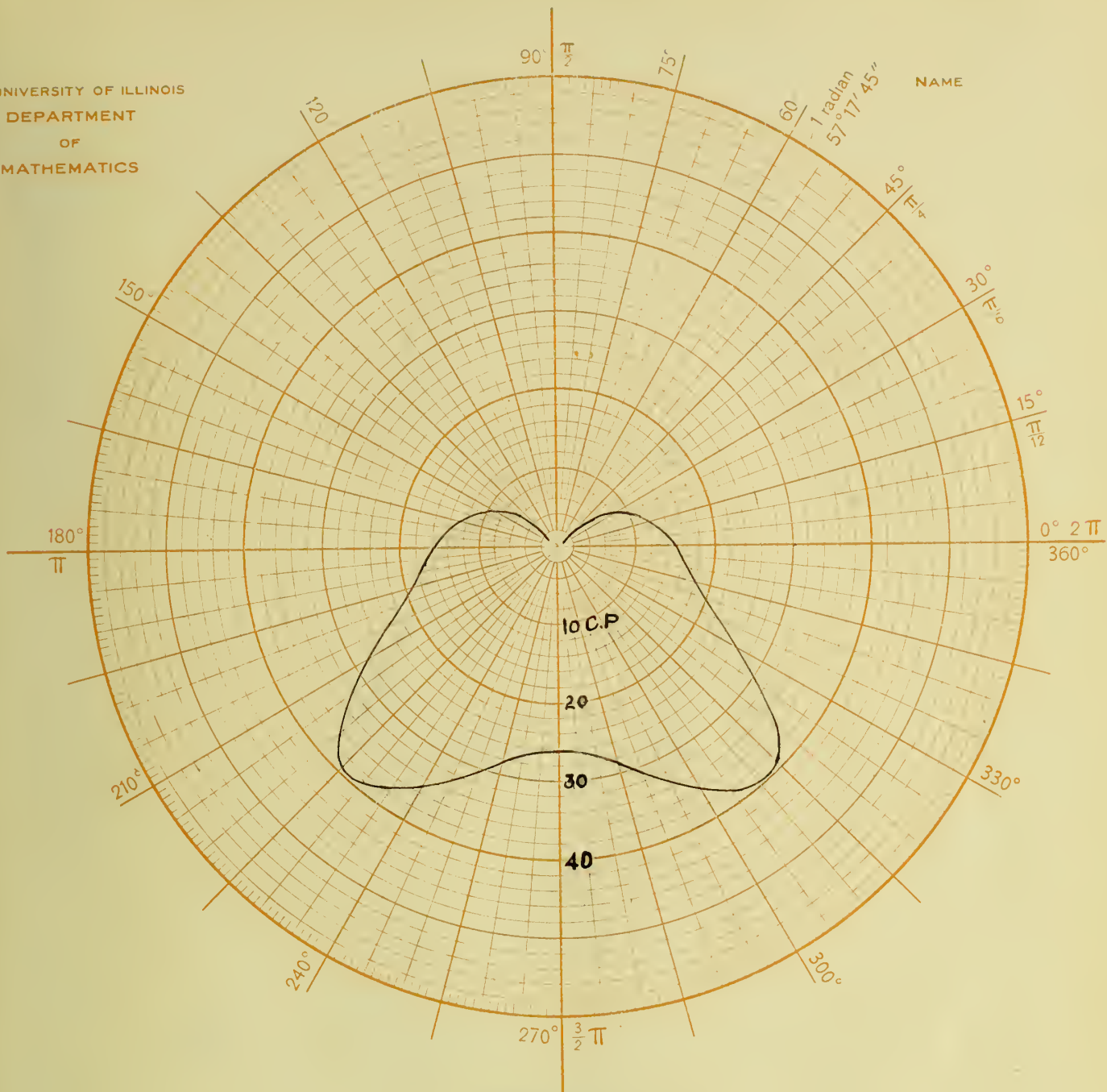


Fig. 4.

Photometric Curve

Extensive type Holophone reflector with 40 watt
tungsten lamp.



THE
NEW
AND IMPROVED
METHOD OF
TEACHING
ARITHMETIC
AND ALGEBRA
BY
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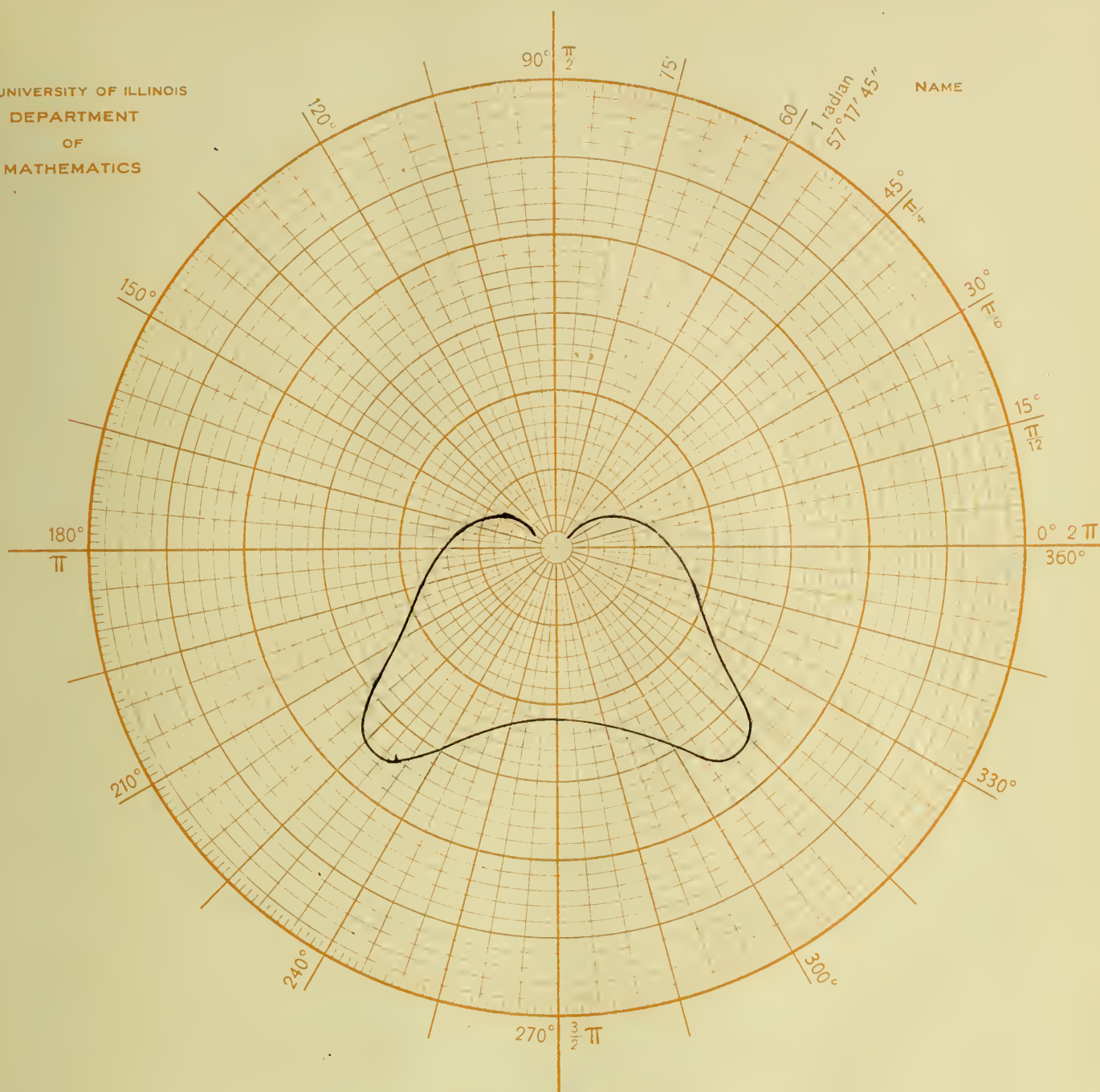


Fig. 5.
Photometric Curve

Extensive type Holophone reflector with 40 watt
tungsten lamp.

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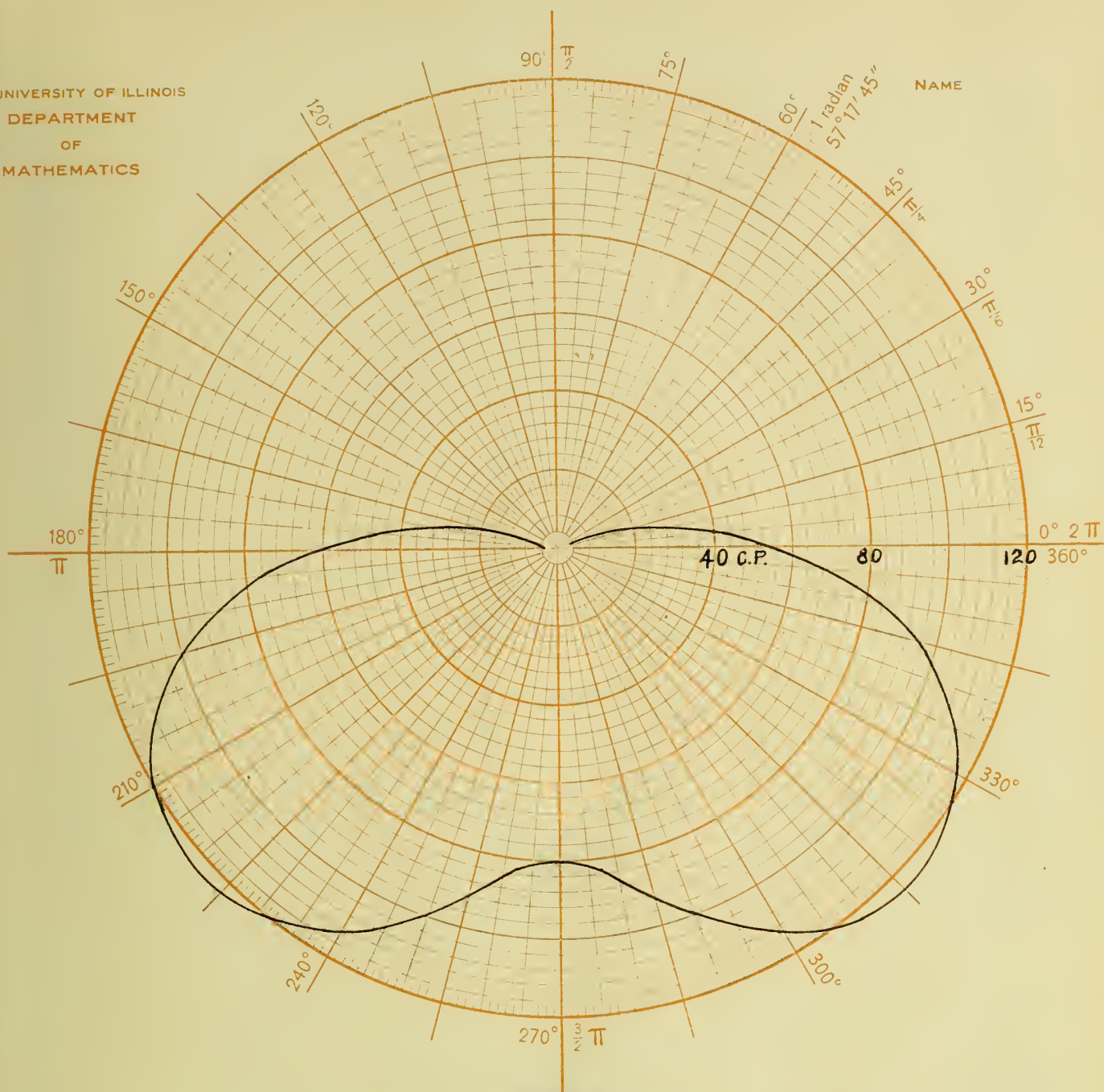


Fig. 6.

Photometric curve of a 100 watt tungsten lamp
fitted with a steel reflector of the Extensive type.



FIG. 1.

Diagram illustrating the distribution of the population of the United States in 1850.

The diagram shows the United States divided into states and territories, with the population of each area indicated by the number of dots placed within its boundaries. The dots are arranged in a grid-like pattern, with the density of dots representing the population density of the area.

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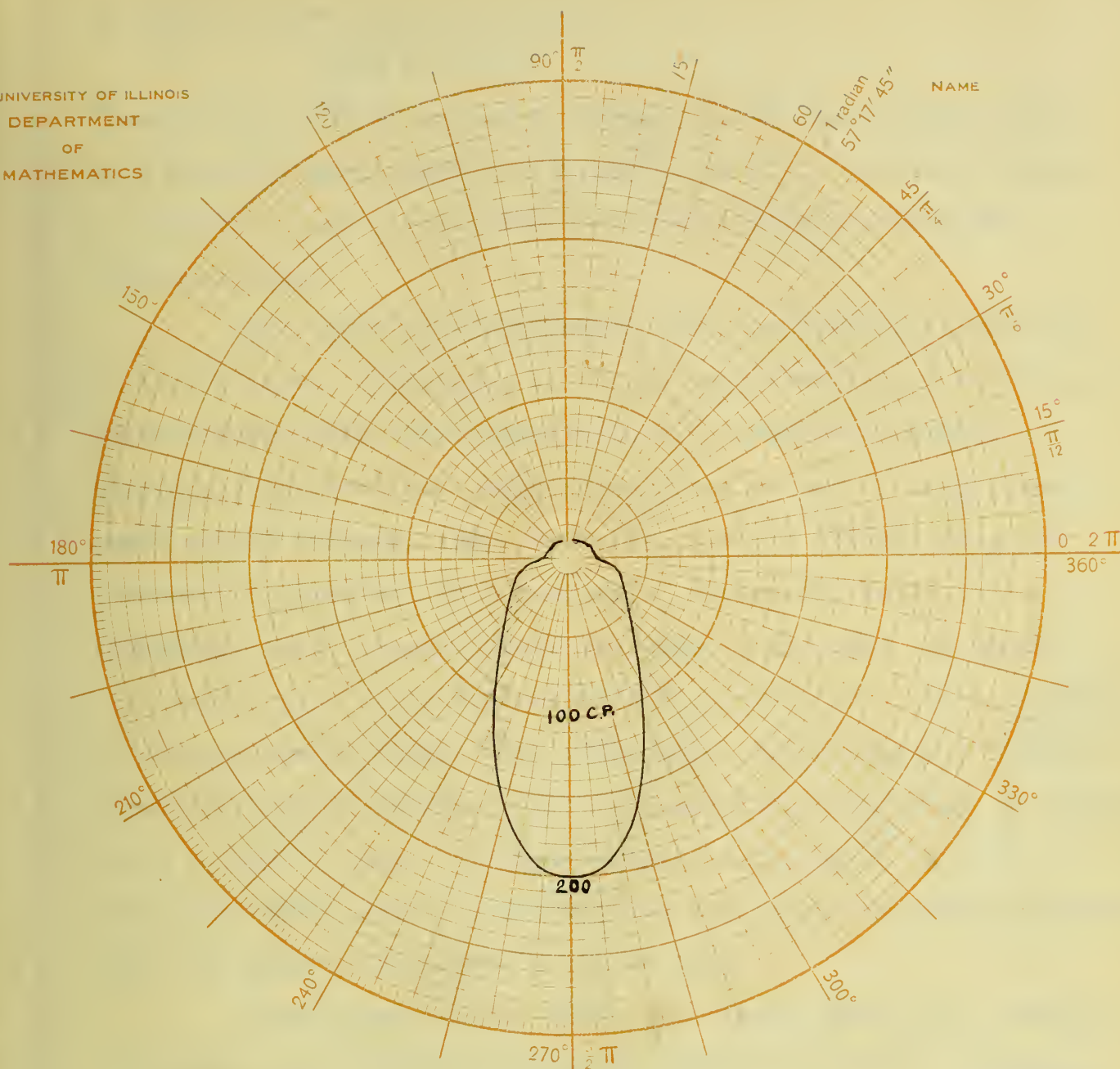


Fig. 7

Photometric curve of a 60 watt tungsten lamp
fitted with a focusing type Holophone reflector.



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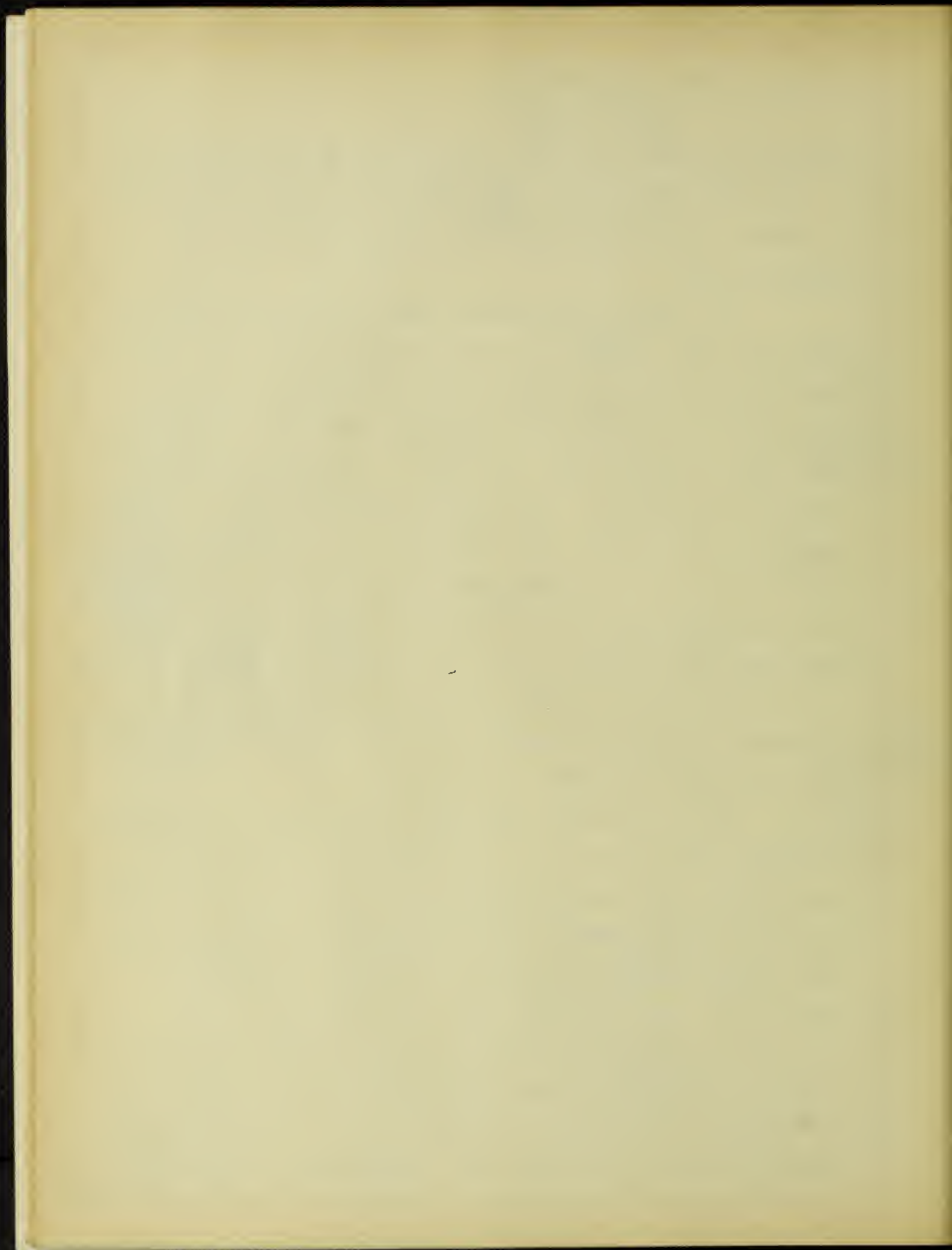
of light to the point considered.

$$\text{Then } \frac{H}{D} = \cos \theta$$

Therefore $D = \frac{H}{\cos \theta}$ and as $H_h = \frac{I}{D^2} \cos \theta$, by substituting for D , $E_h = \frac{I}{H^2} \cos^3 \theta$. Similarly $E_v = \frac{I}{L^2} \sin^3 \theta$. As it is very much easier to measure L than D these are much better formulae than the original ones.

The ordinary incandescent lamp has various intensities in the different directions as can be seen from Fig. 2 and Fig. 3. These figures show the intensity in all directions in both a horizontal and vertical plane through the center of a 200 candle power series tungsten lamp. From Fig. 2 it is evident that the intensity is greatest in a horizontal direction, while it is absolutely zero directly above the socket, and very low at the tip. From Fig. 3 it is evident that the intensity is very uniform in the horizontal plane. With reflectors the intensity in various directions can be varied to suit the conditions as shown by figures 4, 5, 6, and 7. Thus a reflector may be selected which will distribute the light in practically any way it may be wanted depending upon the class of work that is to be done.

Some rooms require more light than others, for instance a drafting room must be much better illuminated than a hall or lecture room. Consequently, lighting is divided into several classes as follows, bright, medium, and low. There are no sharp division lines between the different classes, but bright illumination would be that where there are only 2 or less square feet of horizontal illuminating surface per M.S.C.P., while medium illumination would be that where there are from 2 to 4 square feet of horizontal illuminating surface per M. S. C. P., and low illumination would be that where there are more than 4 square feet

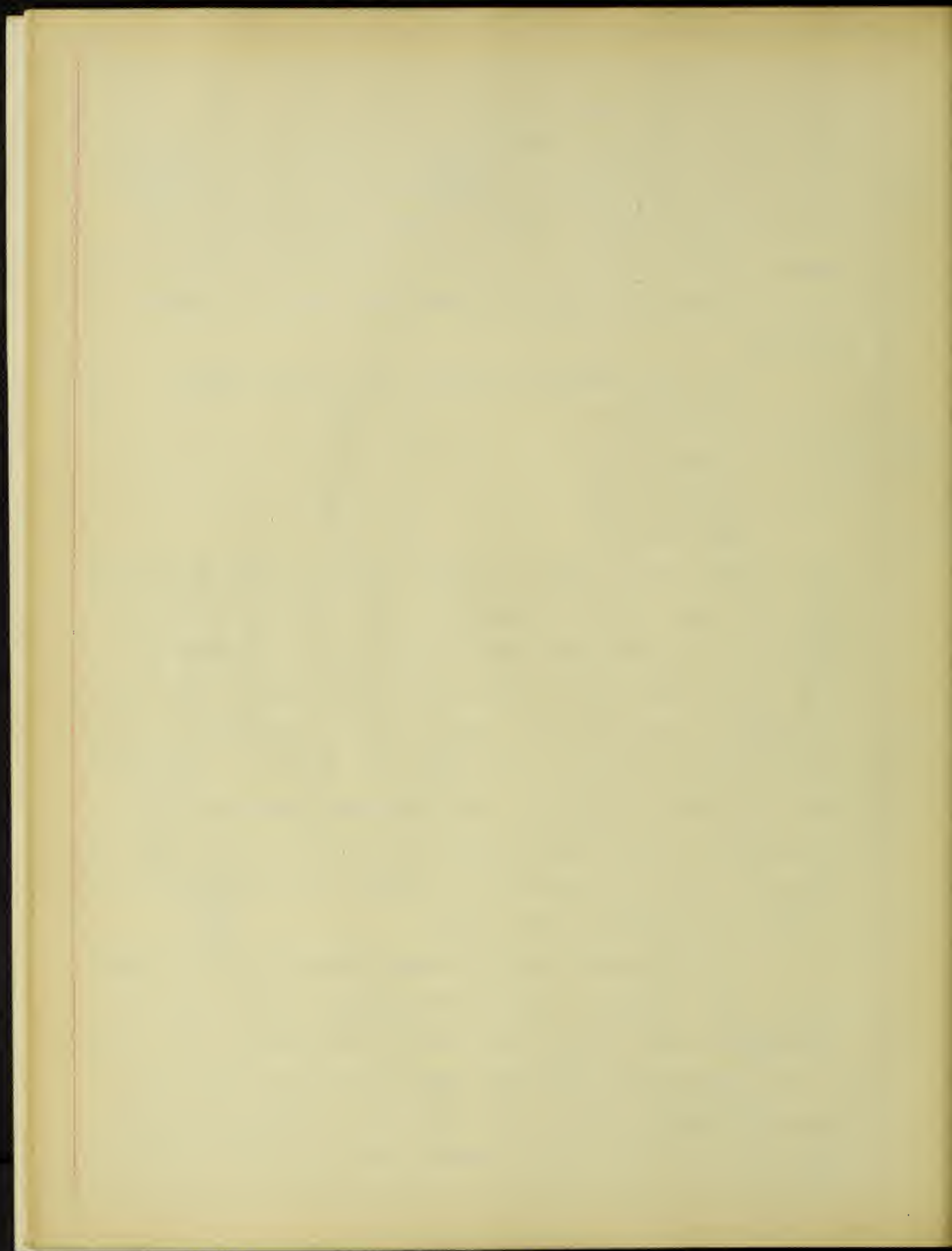


per M.S.C.P. Another way to separate the divisions is as follows:-
 Bright illumination where there are 30 cubic feet or more per M.S.
 C.P., Medium illumination where there are 30 to 60 cubic feet per
 M.S.C.P., and Low illumination where there are 60 or more cubic
 feet per M.S.C.P. As the amount of light required for any room
 depends upon the purpose of the room, the following table has been
 prepared showing the amount of illumination needed for various
 purposes.

Halls and Corridors require	.5 to 1 foot candles.
Auditoriums	" 1. to 3 " "
Reading Rooms	" 2. to 4 " "
Drafting Rooms	" 5. to 10 " "
Desk lighting	" 2. to 5 " "

Store lighting depends upon the goods handled as some goods absorb more light than others. For instance a store where dark goods as clothing are handled would require almost as much illumination as a drafting room, while a store where light goods as china-ware are handled would require only about as much illumination as an ordinary office building. If the walls and ceiling of a room are light in color the effect of a given lighting system would be considerably greater than if they were dark. Thus if the rooms are finished in white the system will be almost twice as effective as if they were finished in dark colors.

In calculating the size number and spacing of the lamps for any room for direct lighting, many things must be taken into consideration. The outlets must be as few as possible, yet to give an even distributed illumination they should be not more than 10 or 12 feet apart or about 5 or 6 feet from the walls. Of course the installation cost will be smaller when the outlets are few in



number. Also the larger the lamp the smaller the cost per candle power as a 100 watt lamp costs only \$1.35 while four 25 watt lamps giving the same amount of light would cost \$2.60 almost twice as much, two 40 watt lamps while developing only $4/5$ as much light as the 100 watt lamp would cost five cents more than that lamp. Also the more lamps the greater the number of reflectors and globes needed. Thus while good illumination demands many outlets the cost of installation and up-keep tend to keep the number of outlets down.



PART I.

Method of Calculating for Direct Lighting.

One way of calculating the size and number of lamps required in any room is to assume the number of cubic feet per mean spherical candle power to be allowed. Then to find the number of mean spherical candle power needed all that is necessary to do is to divide the number of cubic feet of space in the room by the number of cubic feet per mean spherical candle power. The next thing is to decide upon the arrangement of the arrangement of the lamps and after that the number and kind.

Now from table no.1, and the

Table No. 1.

total M.S.C.P. needed as found above, the number that is needed of any kind of lamp may be found. After the kind, number, and arrangement of the lamps	Size of Lamp in Watts. 25 40 60 100 150	M.S.C.P. 15.6 24. 37. 62.5 94.
---	---	---

and reflectors has been decided upon, the amount of illumination on the plane where the light is wanted must be calculated in order to check the results.

The lighting of six rooms was calculated by the method indicated above. These rooms have been numbered 1 to 6 inclusive for the sake of reference, and are situated in Lincoln Hall, University of Illinois. At present they are lighted by the indirect method.

Room 306 is marked No. 1

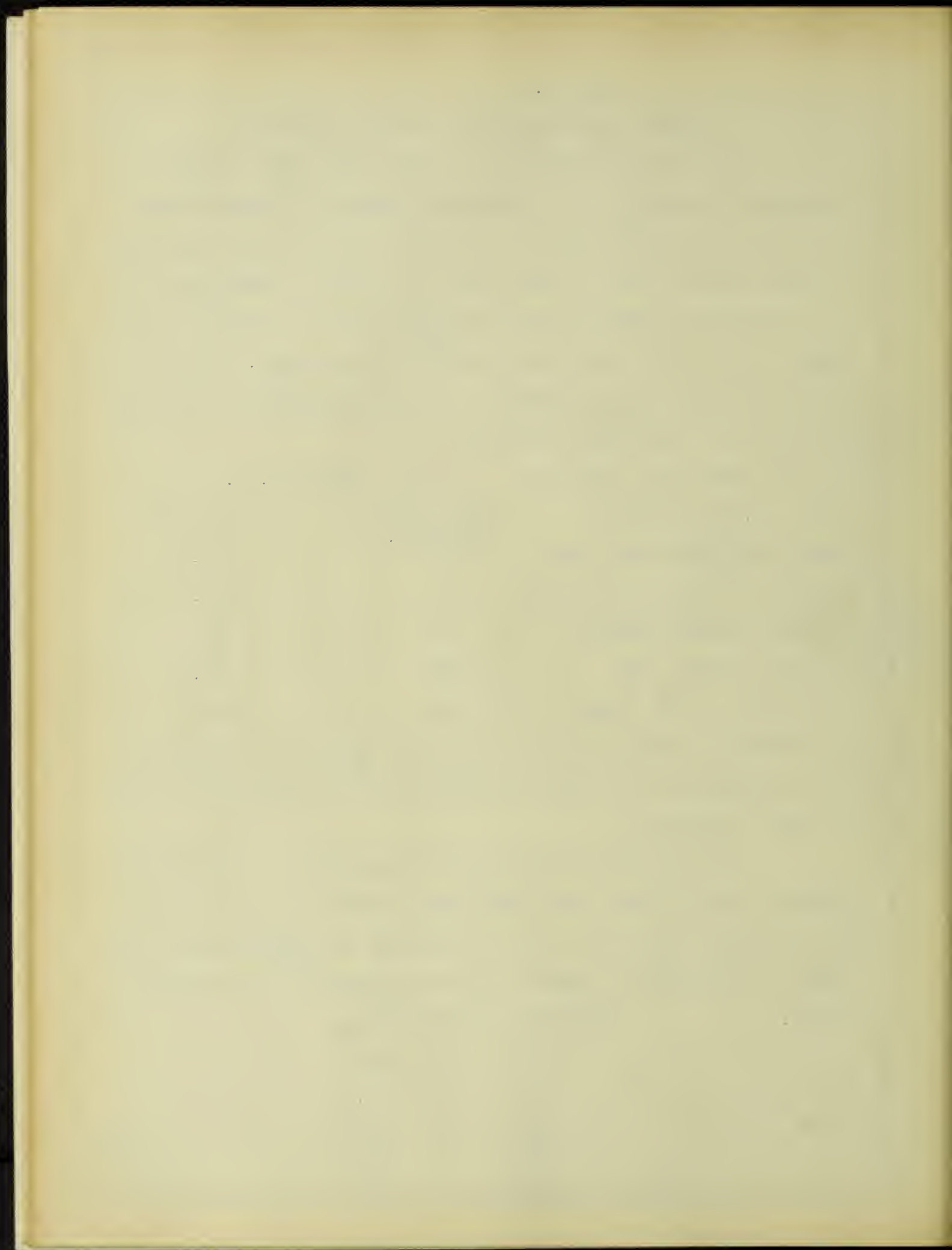
" 108 " " No. 2

" 117 " " No. 3

" 108 " " No. 4

" 214 " " No. 5

Womans Rest Room " " No. 6



Calculations of Direct Lighting for the 6 Rooms Mentioned Above.

The dimensions of room No. 1 are as follows, length 25 feet, width 25 feet, height $13\frac{1}{2}$ feet, and volume 8450 cu.ft. This room is a lecture room so 40 cu.ft. were allowed per M.S.C.P. Therefore $8450 \div 40$ or 211 M.S.C.P. are needed. From Table No.1 it is evident that this room would require 13.6 - 25 watt lamps, 8.8 - 40 watt lamps, 5.7 - 60 watt lamps or 3.4 - 100 watt lamps. From an inspection of the room (Fig. 8a) it is seen that it would be best to arrange the lamps in four clusters, consequently there must be four or some multiple of four lamps in the room. By choosing 100 watt lamps with enameled steel reflectors and putting them $6\frac{1}{2}$ feet from either wall (see Fig. 8a) , enough illumination will be obtained and this illumination will be fairly evenly distributed. The lamps would be hung 3 feet from the ceiling and as the working plane is $2\frac{1}{2}$ feet from the floor, they will be 8 feet from the plane to be illuminated.

Now as the horizontal illumination is equal to $\frac{I}{H^2} \cos^3 \theta$, and as the illumination at many places is to be calculated, tables 3, 4, and 5 were calculated. A curve was plotted between L and E_h for each of these tables, L being plotted as abscissa and E_h being plotted as ordinates. These curves and tables were then used in the calculation of the illumination at any point, table No.3 being for a 40 watt lamp, table No. 4 for a 60 watt lamp, and table No. 5 for a 100 watt lamp. As one 100 watt lamp per cluster was used for this room ,table No. 5 with its corresponding curve was used in the calculations.

From this table the illumination at various places in the room (marked a, b, c, d, etc. in Fig. 8a) was calculated by adding the amount of light received from each lamp together. Now



as the room has light colored walls and ceiling 40% was added to these figures because of the light reflected from them. In this way the illumination was found to vary from 1.2 foot candles at the corners to 3.45 foot candles near the center of the room. Table No.6 shows the amount of illumination at all the points marked in figure 8a. In this figure lines were drawn connecting points of equal illumination. Also from this figure it is evident that the illumination in almost all parts of the room is greater than 2 foot candles, which is all that is required in a lecture room. Figures 8b and 8c are cross sections through various parts of the room showing the distribution of the illumination.

In this way the lighting of the other five rooms was calculated . These results are tabulated in tables No. 2, 7, 8, 9, 10, and 11, and diagrams of the room showing the distribution of the illumination similar to figures 8a, 8b, 8c, were drawn (see figures 9a, 9b, 9c, 9d, 10a, 10b, 10c, 10d, 11a, 11b, 11c, 11d, 12a, 12b, 12c, 12d, 13a, 13b, 13c, and 13d).



TABLE No. 2 (Part 1)

Room	No. 1	No. 2	No. 3
Length	25'	25'	30½'
Width	25'	16'	18½'
Hight	13½'	13½'	13½'
Volume	8450 cu. ft.	5450 cu. ft.	7630 cu. ft.
Purpose	Lecture	Class	Class
Cu ft. per M.S.C.P.	40	30	30
No. lamps	4	5	6
Kind "	100 watt	60 watt	60 watt
" reflector	Extensive type steel	Extensive type Holophone	Extensive type Holophone
Distance from lamp to illuminating plane	8'	8'	8'
Arrangement of lamps	4 clusters 1 lamp each	5 clusters 1 lamp each	6 clusters 1 lamp each

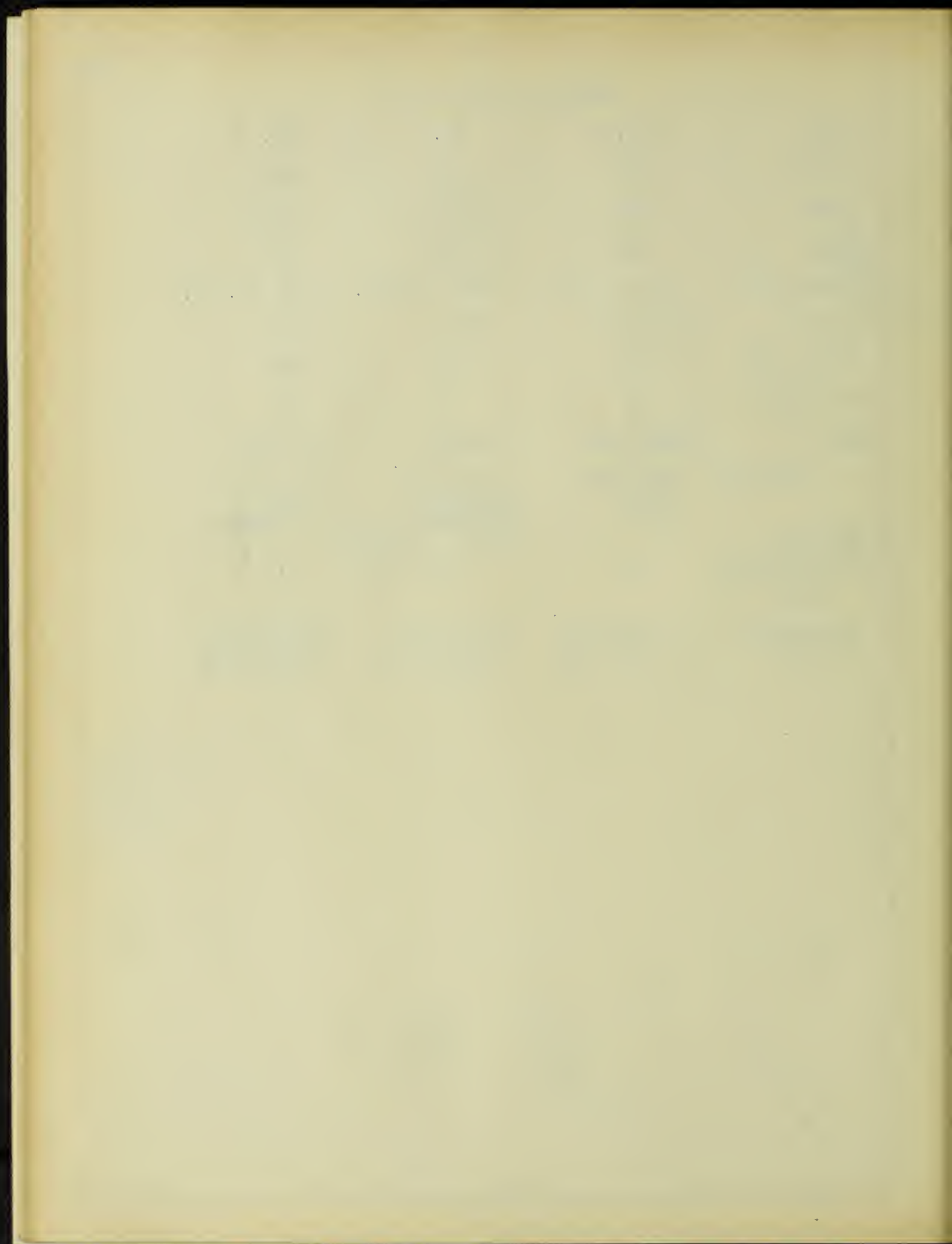


TABLE No. 2 (Part 2)

Room	No.4	No.5	No.6
Length	39'	18 $\frac{1}{2}$ '	19'
Width	25'	10'	10'
Height	13 $\frac{1}{2}$ '	13 $\frac{1}{2}$ '	13 $\frac{1}{2}$ '
Volume	13800 cu. ft.	2500 cu. ft.	2590 cu. ft.
Purpose	Library	Office	Rest room
Cu. ft. per M.S.C.P.	20	20	30
No. lamps	12	4	6
Kind "	60 watt	60 watt	40 watt
" reflector	Extensive type Holophone	Extensive type Holophone	Extensive type Holophone
Distance from lamp to illuminating plane	8'	8'	8'
Arrangement of lamps	6 clusters 2 lamps each	2 clusters 2 lamps each	2 clusters 3 lamps each



TABLE No. 3

Relation between E and L for 40 watt tungsten lamp with
extension type Holophone reflector

L ft.	θ	Cos θ	I C.P.	H ft.	$H = 8 \text{ ft.}$ $\frac{I \cos^3 \theta}{H^2}$
					ft. candles
0	0	1	26	64	.406
1	7° 8'	.978	26.5	64	.404
2	14° 4'	.91	27.5	64	.392
3	20° 34'	.82	31	64	.396
4	26° 34'	.715	34	64	.380
5	32°	.61	37	64	.352
6	36° 54'	.515	38.5	64	.310
7	41° 12'	.425	39.5	64	.262
8	45°	.355	39.5	64	.218
9	48° 20'	.295	38	64	.175
10	51° 25'	.245	36	64	.134
11	54°	.204	33	64	.105
12	56° 20'	.17	31	64	.082
13	58° 25'	.144	29	64	.065
14	60° 15'	.122	27	64	.052
15	61° 35'	.105	26	64	.043
16	63° 30'	.089	25	64	.035
18	66° 5'	.067	23	64	.024
20	68° 10'	.051	22	64	.018
24	71° 35'	.032	20	64	.010

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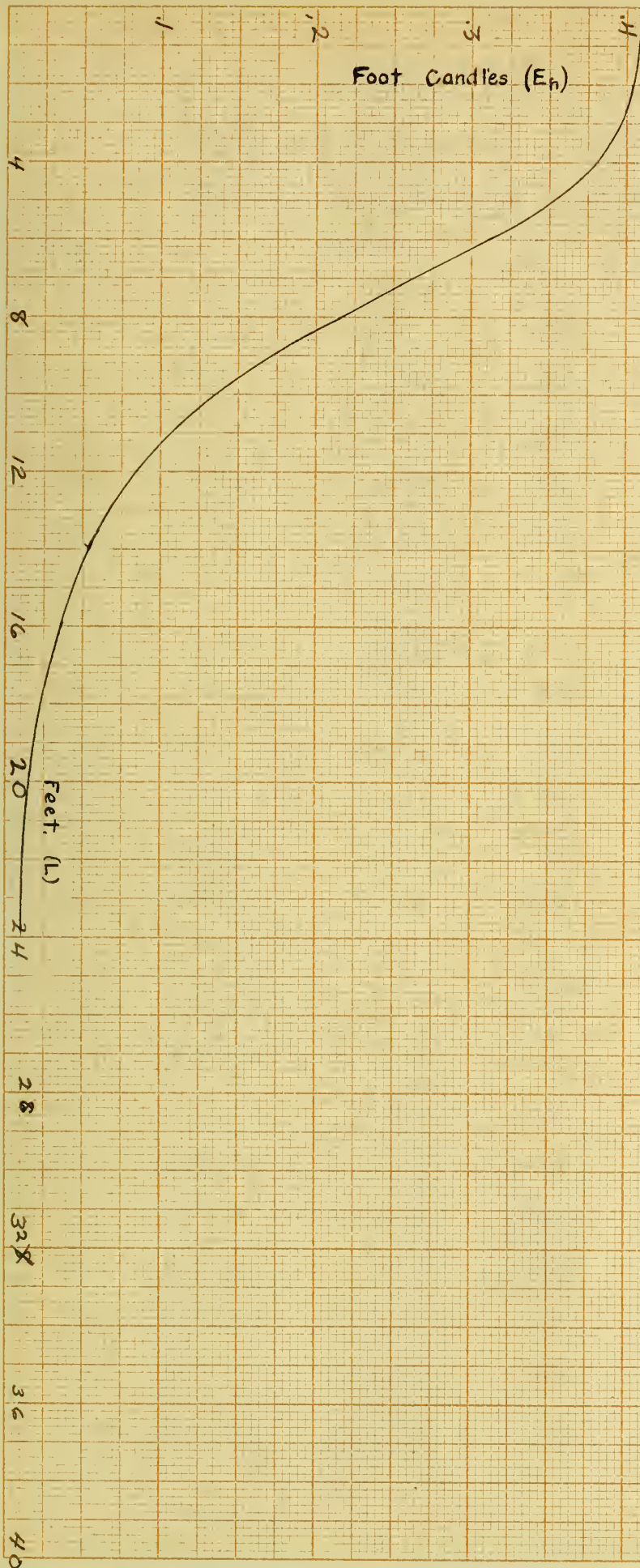
Foot Candles (E_h)Curve showing the relation between L and E_h of Table 3



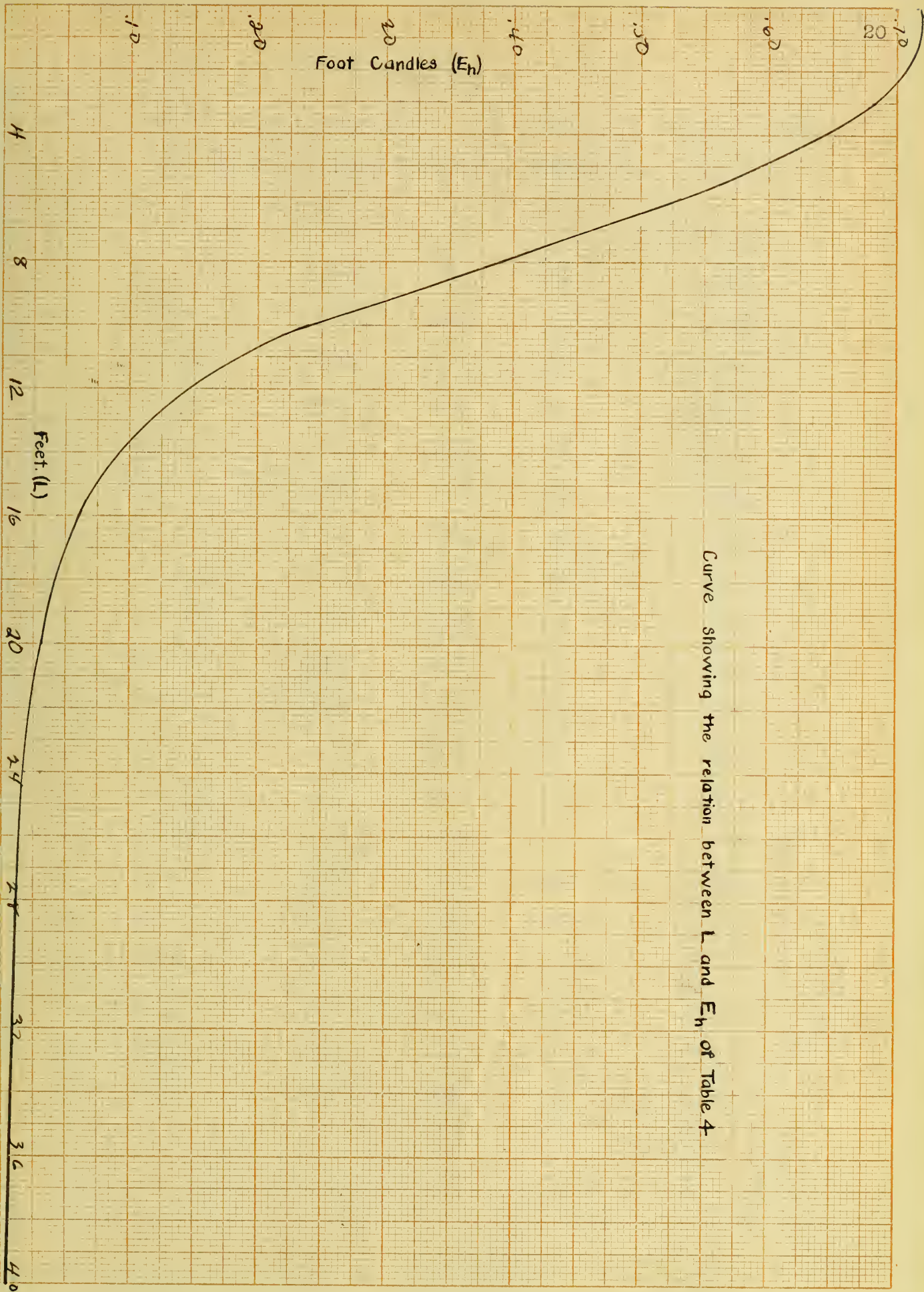
TABLE No. 4

Relation between E and L for a 60 watt tungsten with
extensive type Holophone reflector. H = 8 ft.

L ft.	θ	Cos θ	^a I C.P.	H	E ft. candles.
0	0	1	46	64	.72
1	7° 8'	.978	47	64	.718
2	14° 4'	.910	50	64	.711
3	20° 33'	.820	53	64	.680
4	26° 34'	.7150	56	64	.625
5	32°	.610	62	64	.590
6	36° 54'	.515	66	64	.530
7	41° 12'	.425	71	64	.470
8	45°	.355	70	64	.390
9	48° 20'	.295	68	64	.314
10	51° 20'	.245	62	64	.237
11	54°	.204	59	64	.188
12	56° 20'	.170	55	64	.146
13	58° 25'	.144	50	64	.112
14	60° 15'	.122	47	64	.089
15	61° 35'	.105	45	64	.074
16	63° 30'	.089	44	64	.060
18	66° 5'	.067	41	64	.430
20	68° 10'	.051	39	64	.031
24	71° 35'	.032	37	64	.018
32	76°	.014	35.5	64	.008
40	78° 20'	.007	34.5	64	.004



Curve showing the relation between L and E_h of Table 4



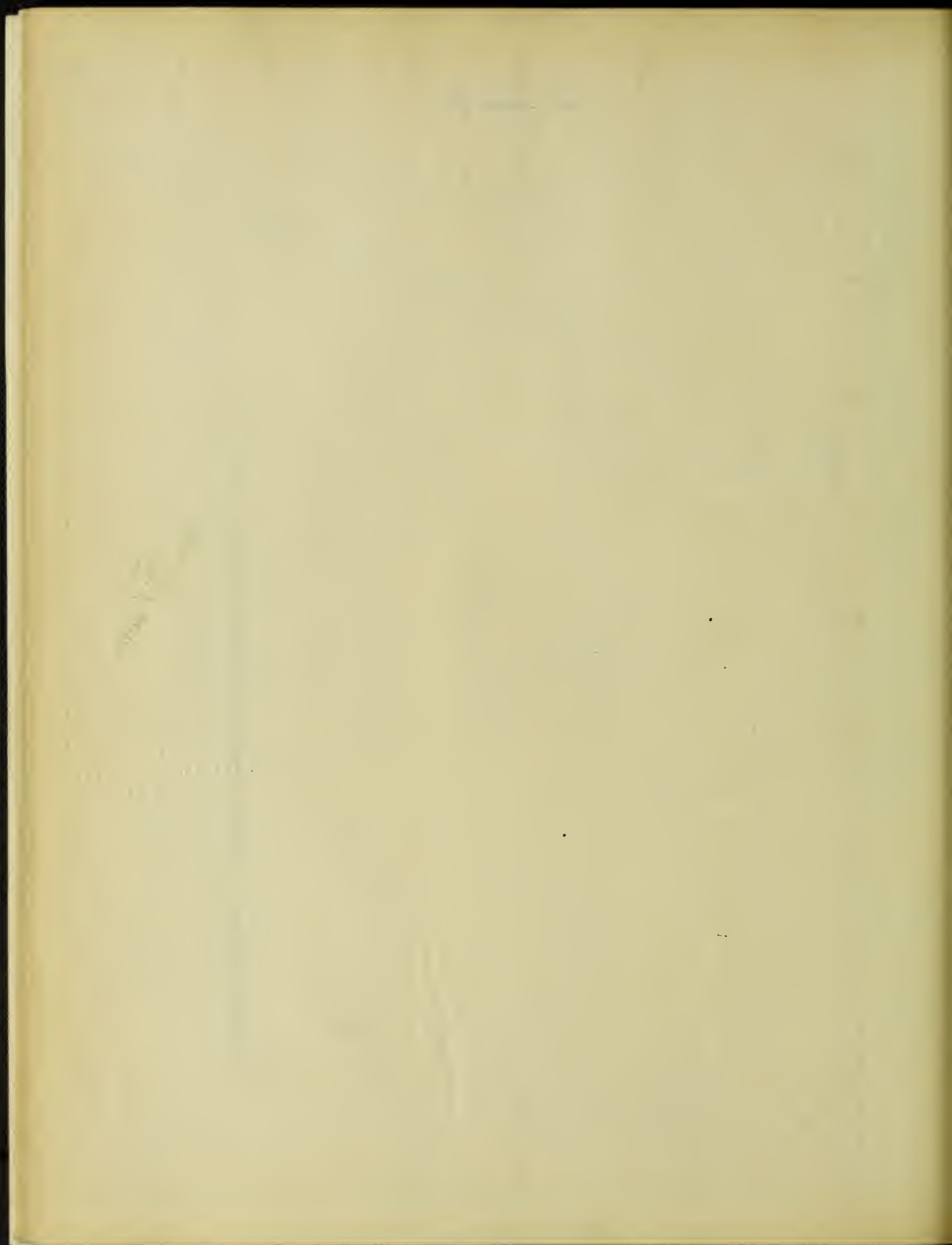
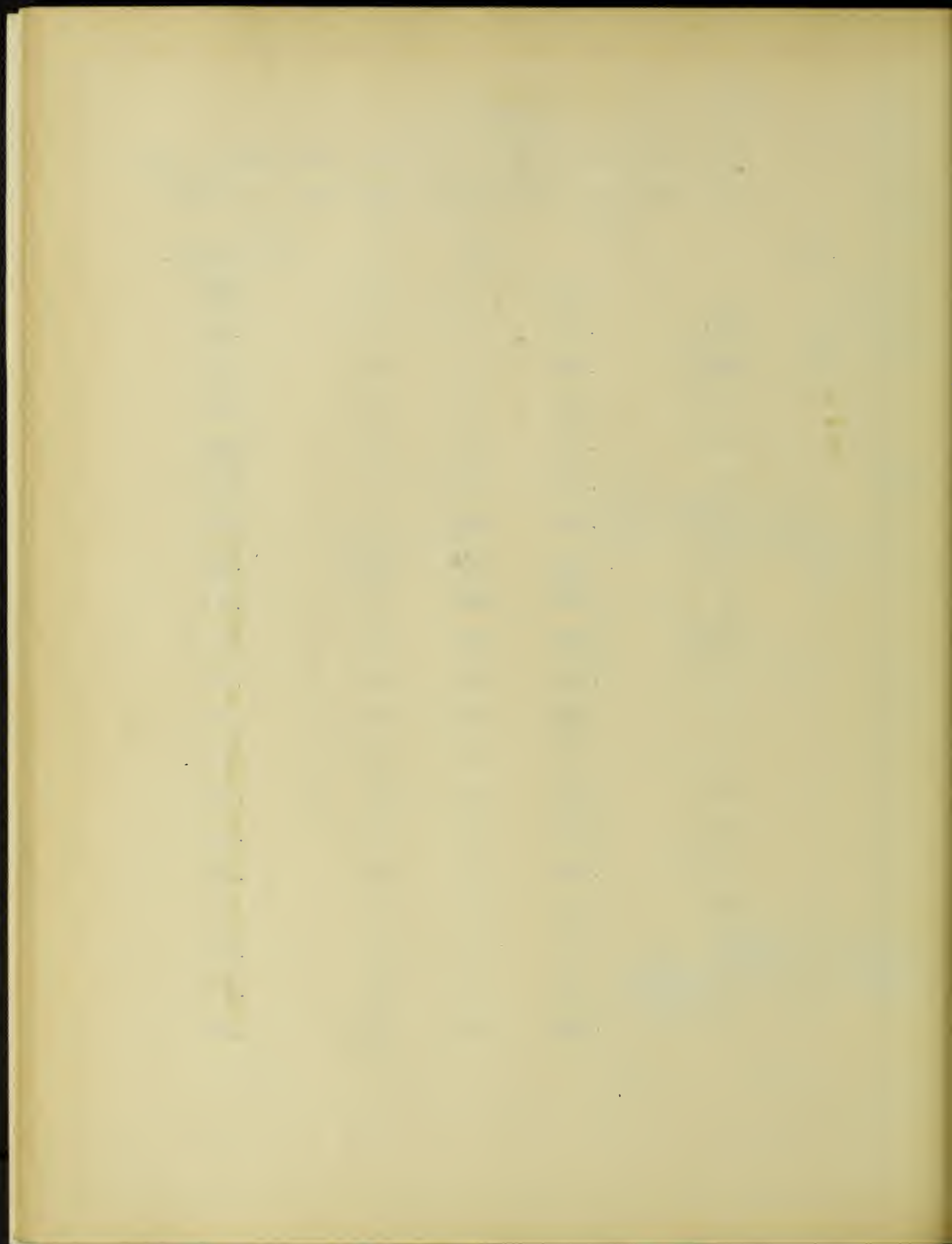
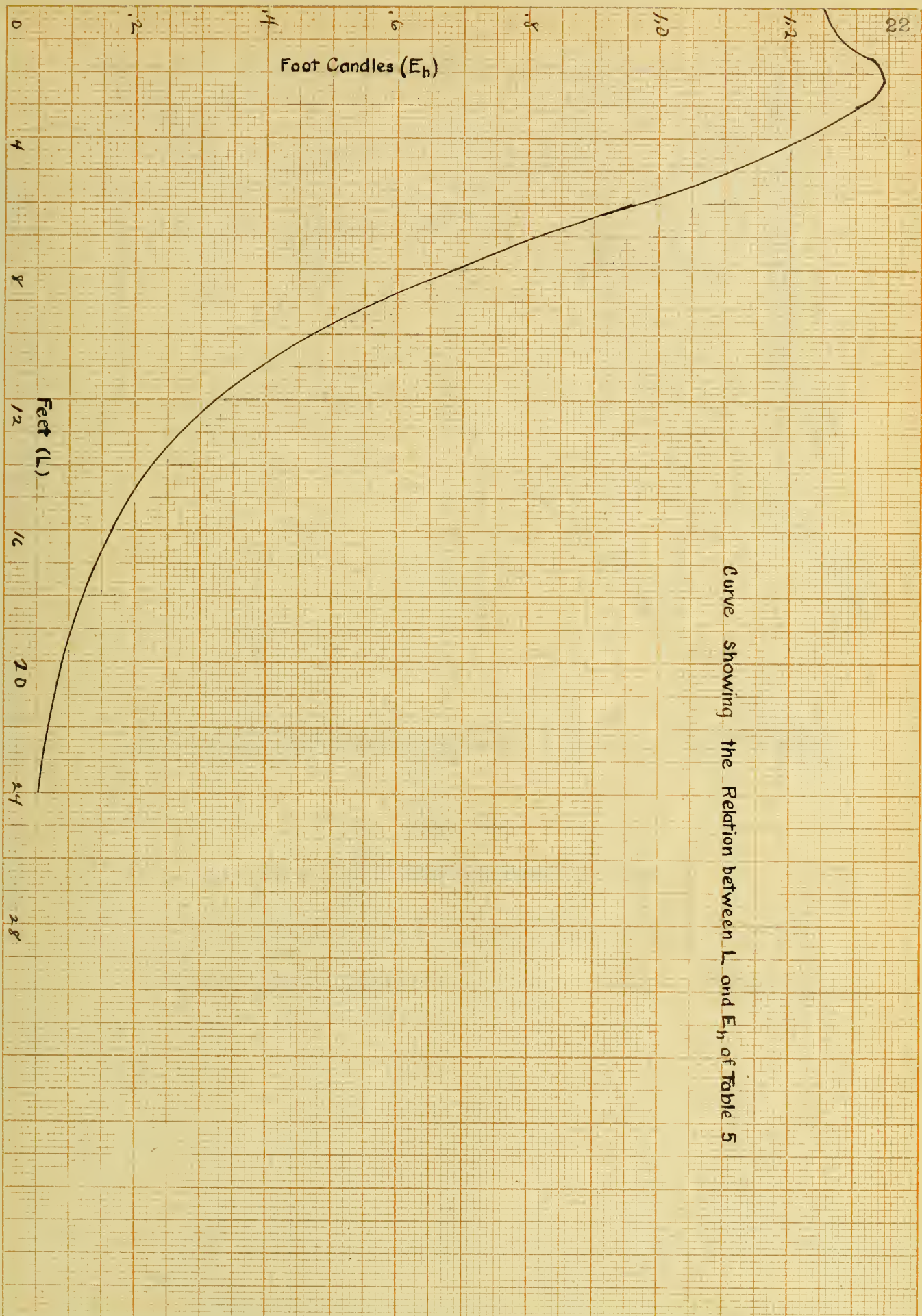


TABLE No. 5

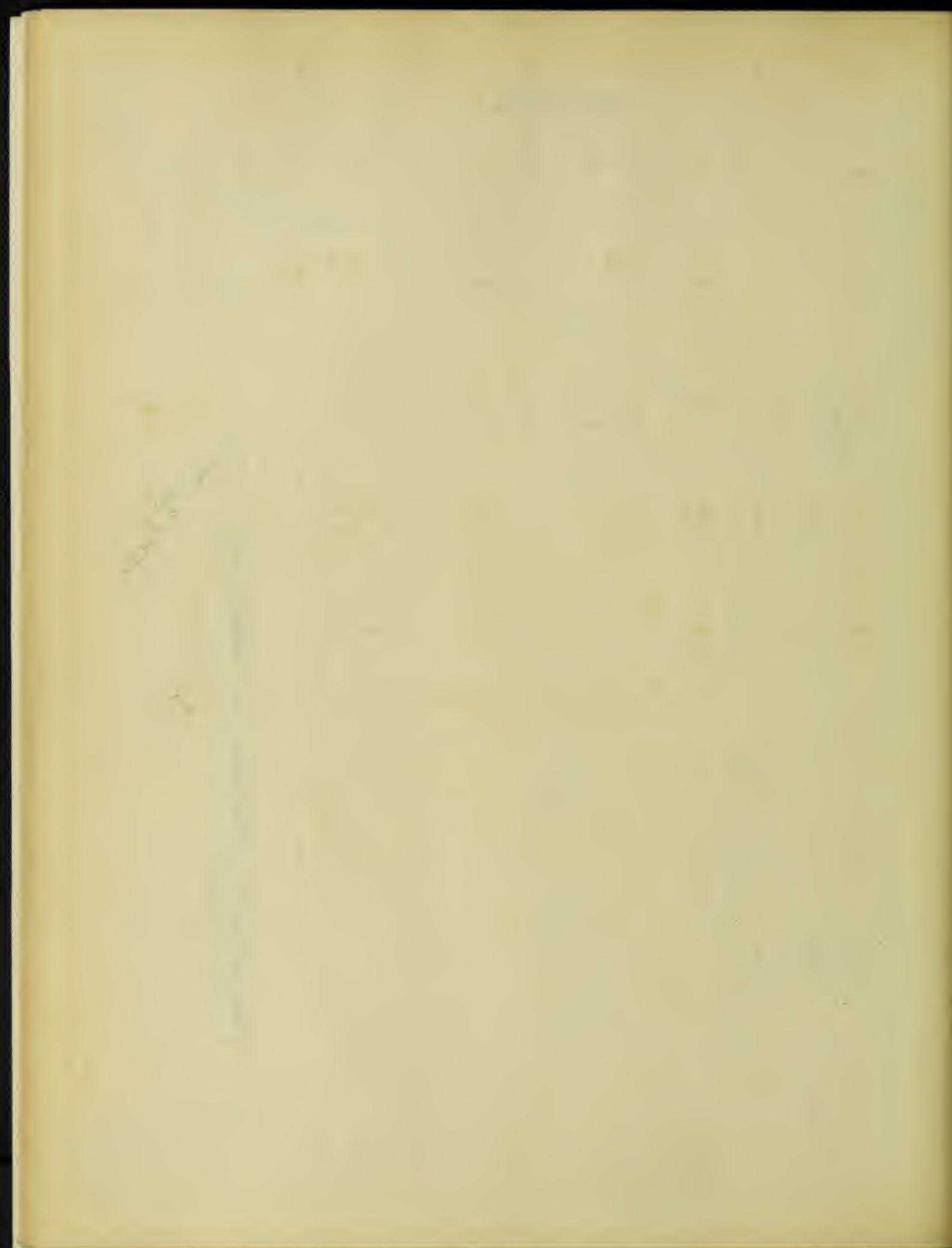
Relation between E and L for a 100 watt tungsten lamp
with extensive type Holophone reflector. $H = 8$ ft.

L ft.	θ	Cos θ	I C.P.	H	E ft. candles.
0	0	1.000	80	64	1.250
1	7° 8'	.978	84	64	1.280
2	14° 4'	.910	94	64	1.340
3	20° 34'	.820	102	64	1.300
4	26° 34'	.715	109	64	1.220
5	32°	.610	115	64	1.100
6	36° 30'	.515	119	64	.955
7	41° 12'	.425	121	64	.804
8	45°	.355	124	64	.683
9	48° 20'	.295	123	64	.567
10	51° 25'	.245	122	64	.466
11	54°	.204	121	64	.396
12	56° 20'	.177	120	64	.319
13	58° 25'	.144	119	64	.268
14	60° 15'	.122	118	64	.225
15	61° 35'	.105	117	64	.192
16	63° 30'	.089	116	64	.161
18	66° 5'	.067	113	64	.118
20	68° 20'	.051	110	64	.088
24	71° 35'	.032	106	64	.053





Curve showing the Relation between L. and E_h of Table 5



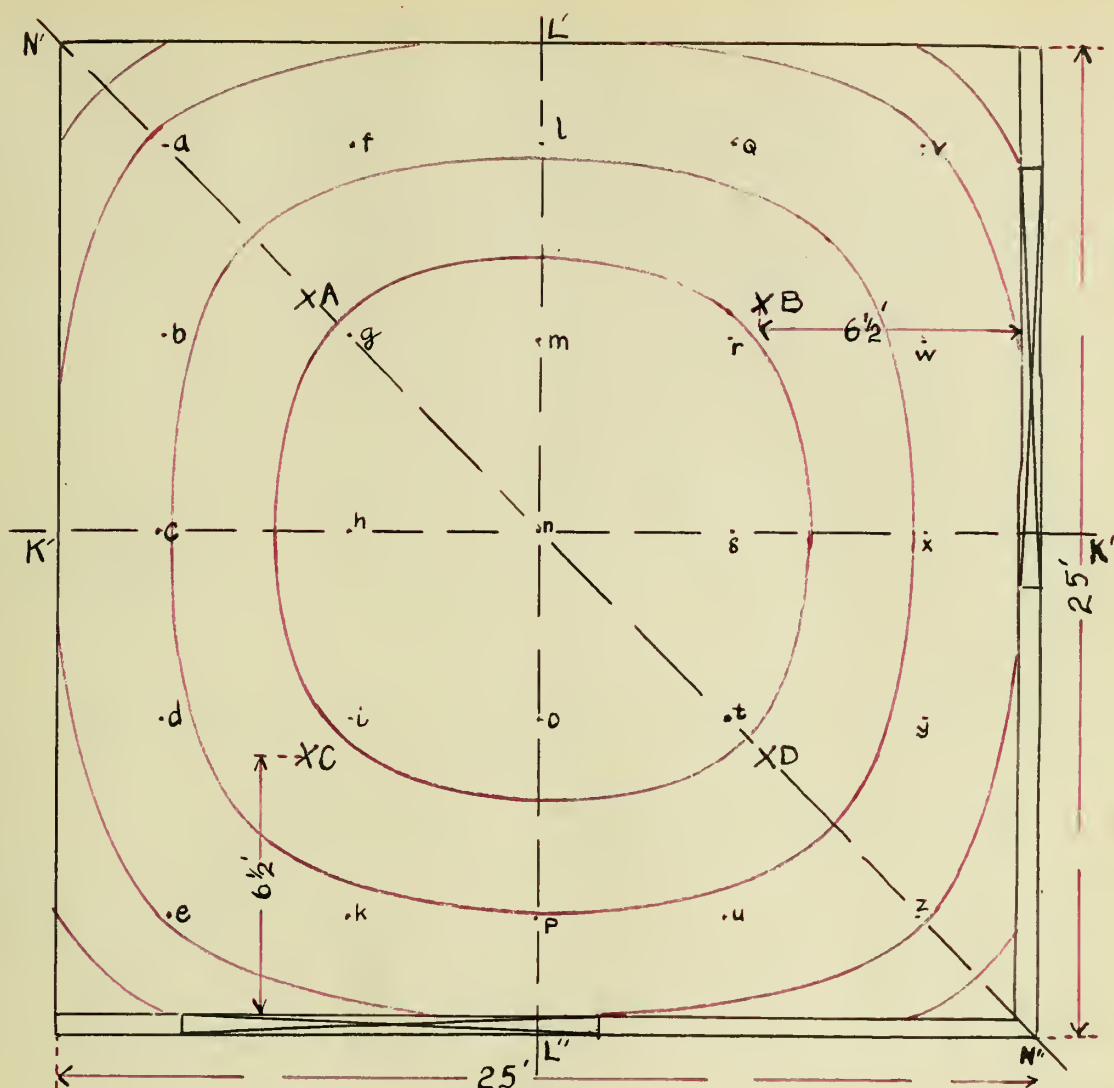


Fig. 8a.

Direct lighting distribution for Room No. 1

• ^a
• ^b) points at which illumination was calculated

X A Lamp clusters (1-100 watt tungsten lamp)

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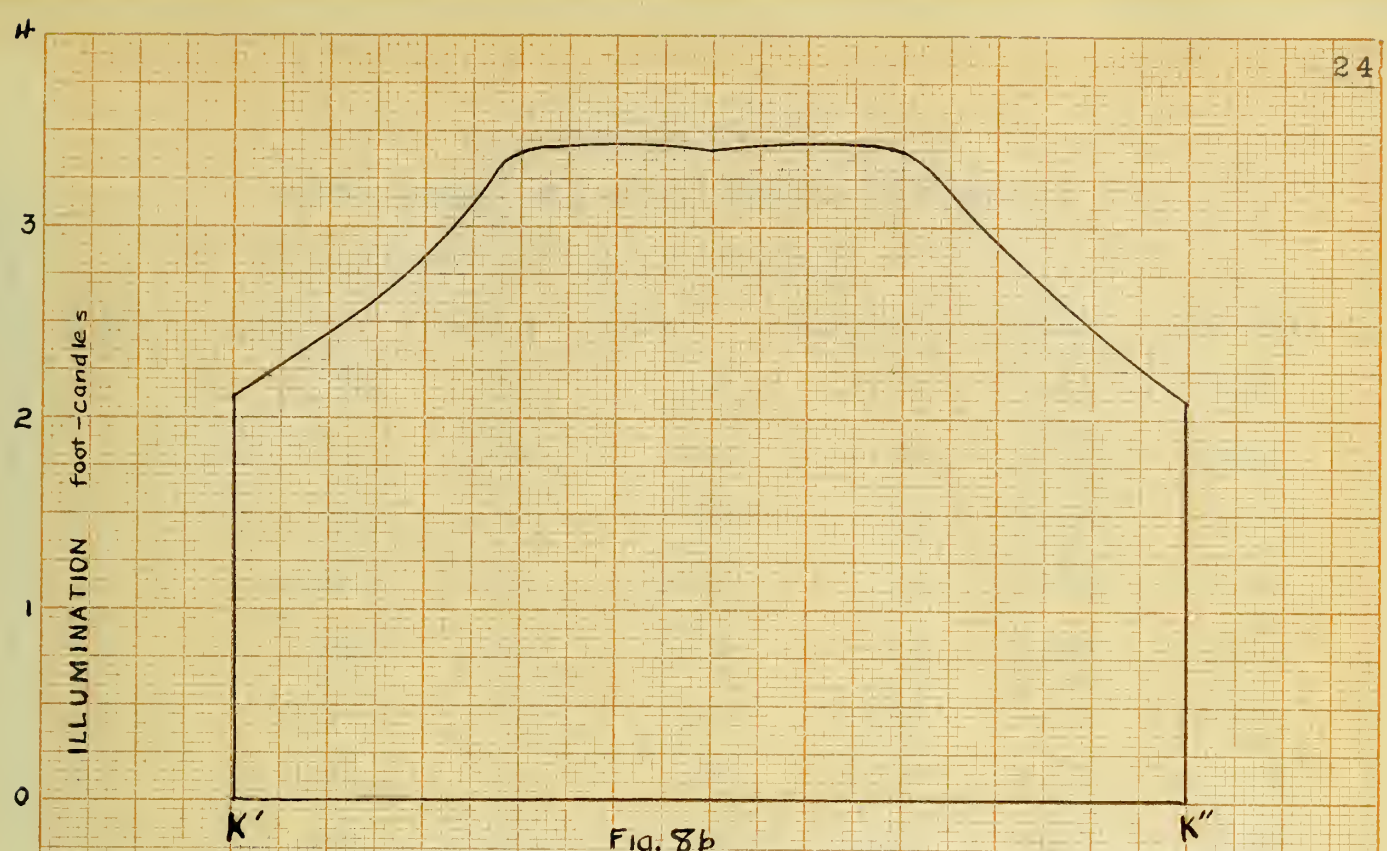


Fig. 8b
Distribution of light along line K'K'' of Fig. 8a
Horizontal scale 1"=5'

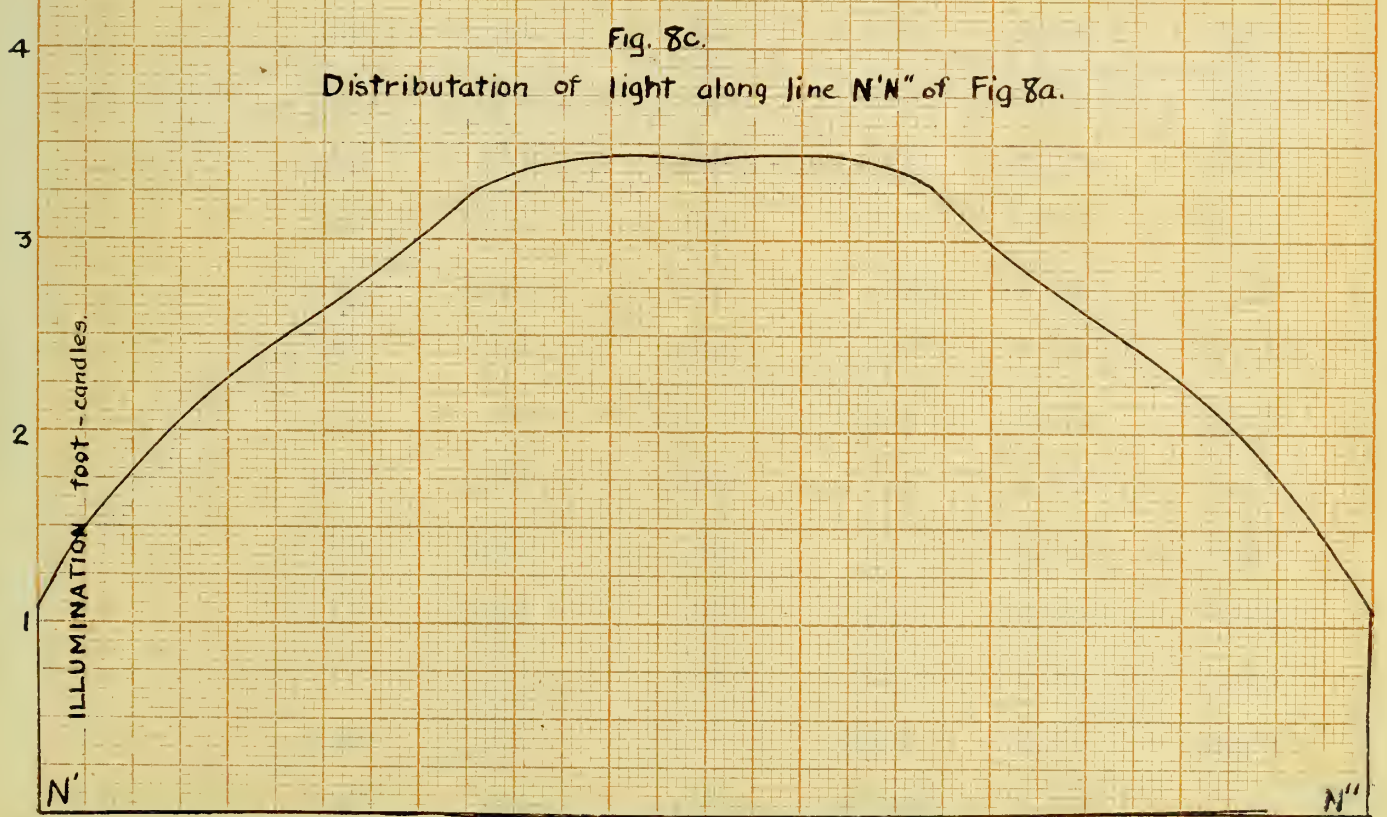


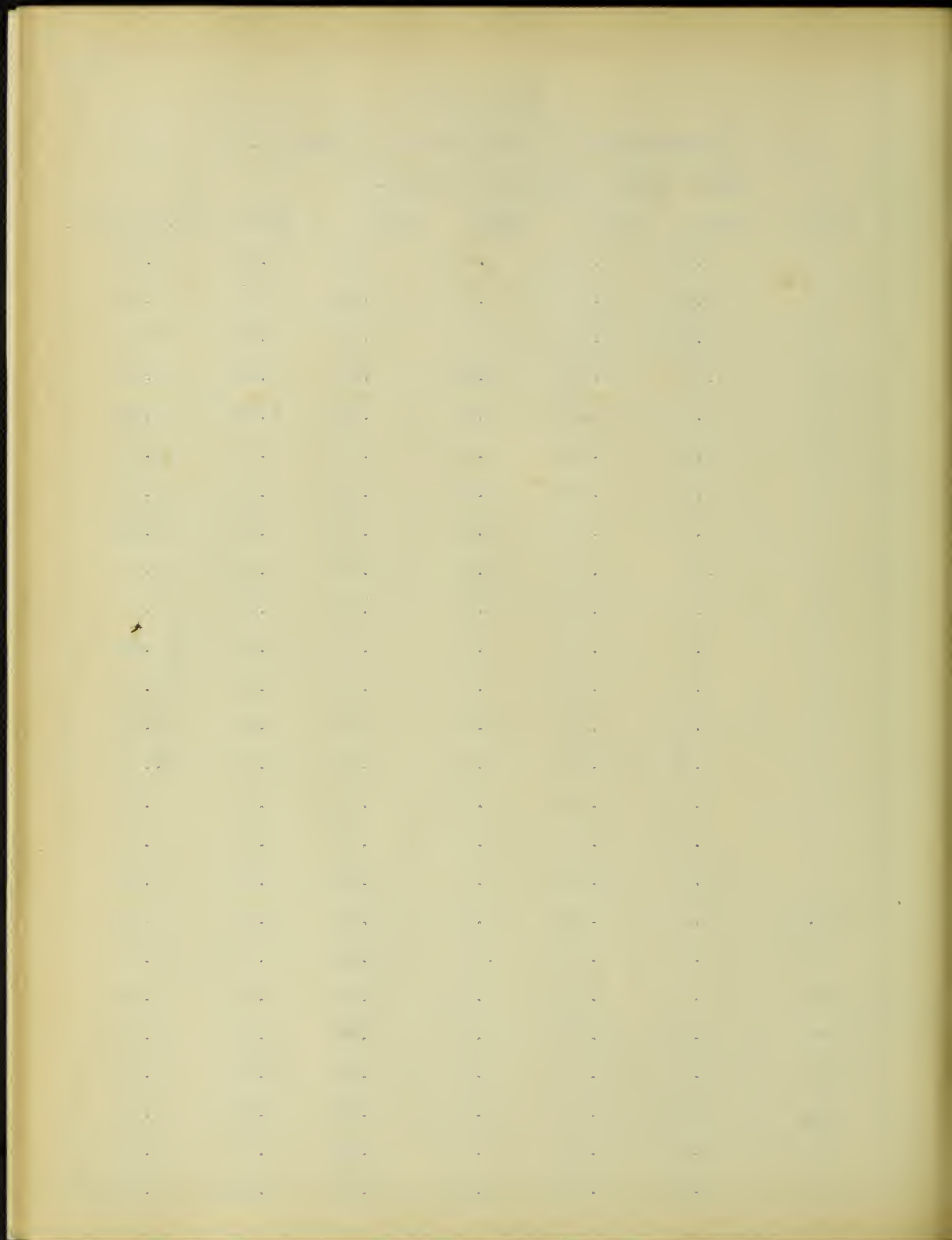
Fig. 8c
Distribution of light along line N'N'' of Fig. 8a.



TABLE. No. 6

Illumination at various points in Room NO. 1
for a direct sustem of lighting.

Point	Lamp A	Lamp B	Lamp C	Lamp d	Total	1.4 Total
a	1.03	.20	.20	.06	1.49	2.08
b	1.18	.16	.32	.09	1.75	2.45
c	.75	.14	.74	.14	1.78	2.49
d	.32	.09	1.18	.16	1.75	2.45
e	.20	.06	1.03	.20	1.49	2.08
f	1.18	.32	.09	.16	1.75	2.45
g	1.31	.37	.37	.14	2.23	3.12
h	.93	.30	.93	.30	2.46	3.44
i	.37	.14	1.31	.37	2.23	3.12
k	.16	.09	1.18	.32	1.75	2.45
l	.75	.75	.14	.14	1.78	2.49
m	.93	.93	.30	.30	2.46	3.44
n	.61	.61	.61	.61	2.44	2.42
o	.30	.30	.93	.93	2.46	3.44
p	.14	.14	.75	.75	1.78	2.49
q	.32	1.18	.09	.16	1.75	2.45
r	.37	1.31	.14	.37	2.23	3.12
s.	.30	.93	.30	.93	2.46	3.44
t	.14	.37	.37	1.31	2.23	3.12
u	.09	.16	.32	1.18	1.75	2.45
v	.20	1.03	.06	.20	1.49	2.08
w	.16	1.18	.09	.32	1.75	2.45
x	.14	.75	.14	.75	1.78	2.49
y	.32	.16	.09	1.18	1.75	2.45
z	.06	.20	.20	1.03	1.49	2.08



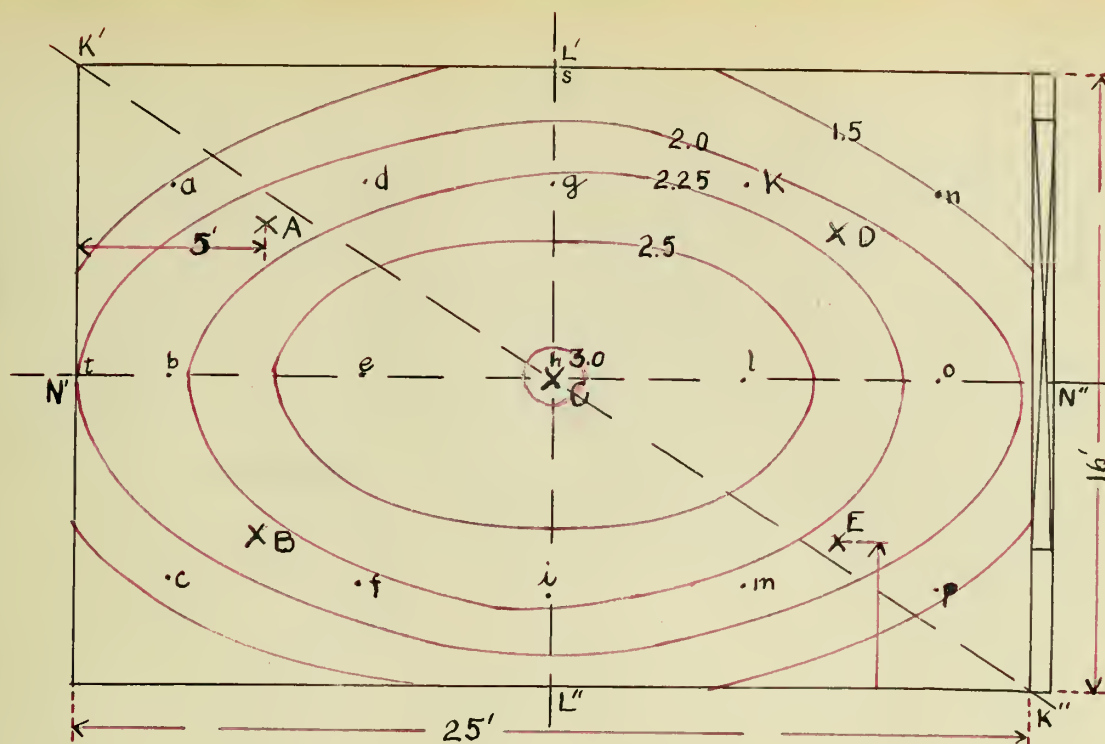


Fig. 9a.

Direct lighting distribution for Room No. 2

• a) points at which illumination was calculated
• b)

XA Lamp clusters (1-60 watt tungsten lamp)

Scale 1" = 5'

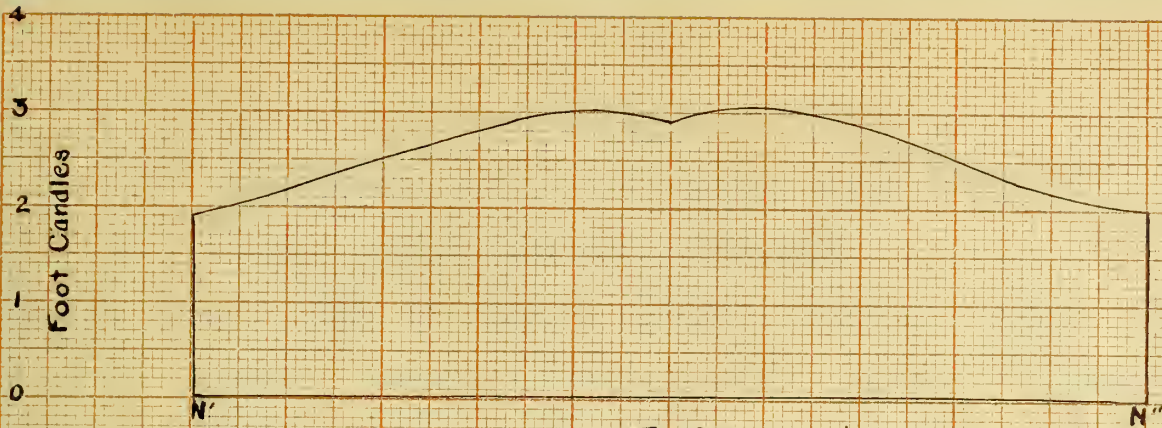


Fig 9b
Distribution of light along line N'N'' of Fig 9a
Horizontal scale 1"=5'

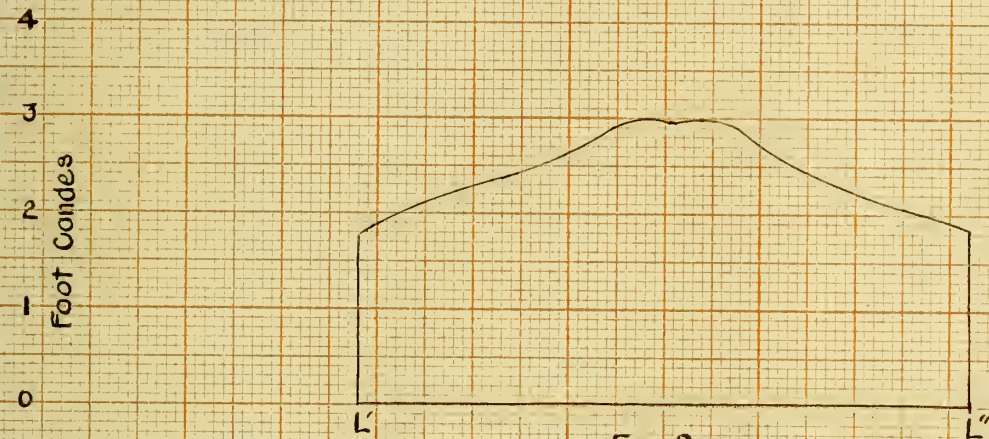


Fig 9c
Distribution of light along line L'L'' of Fig 9a

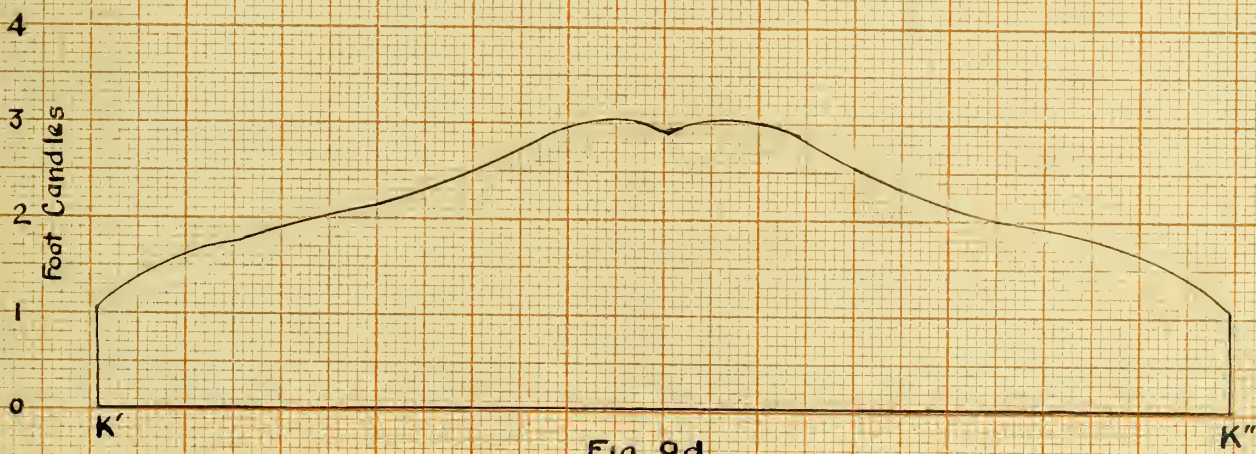


Fig 9d
Distribution of light along line K'K'' of Fig 9a

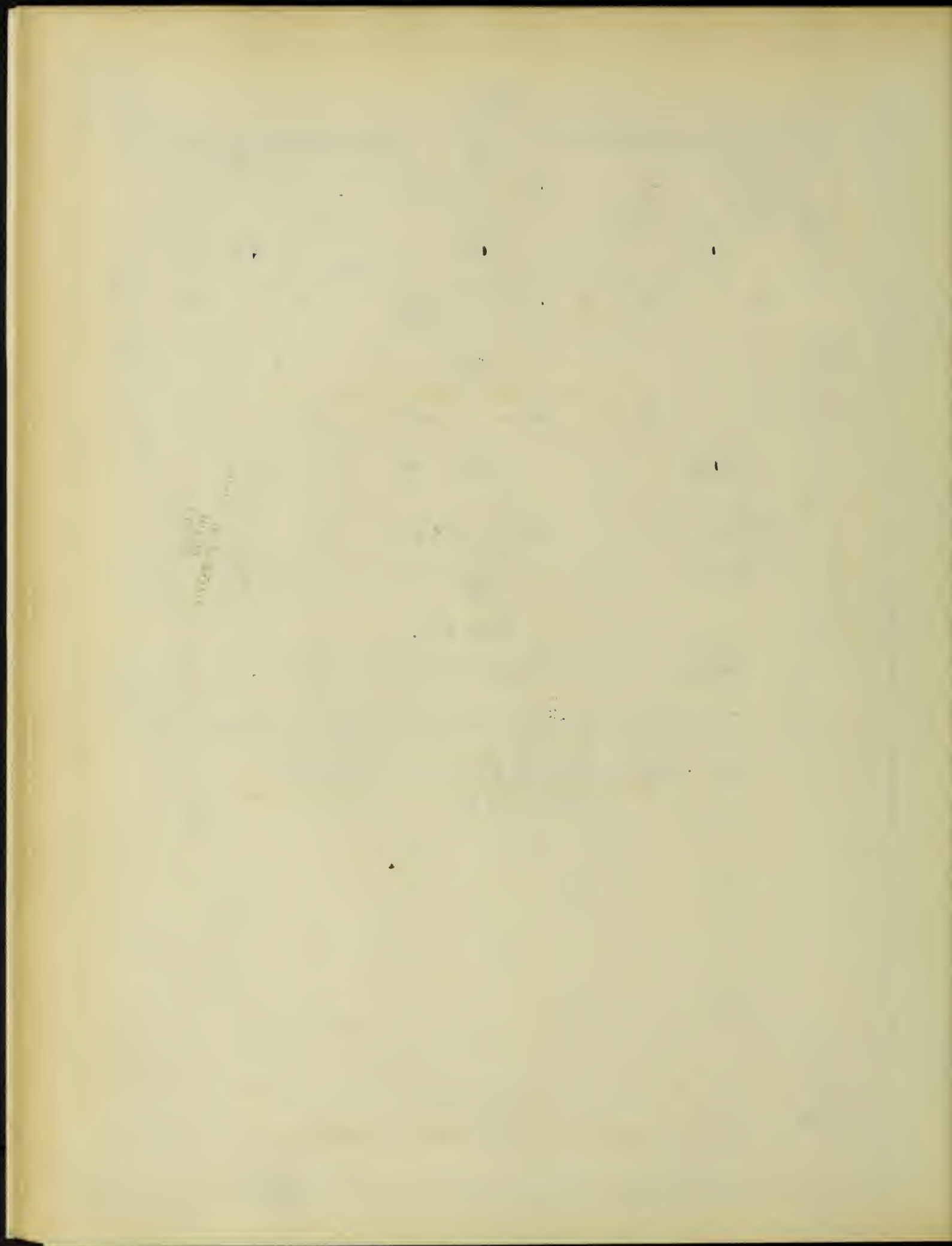
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TABLE No. 7

Illumination of various points of Room No.2

for a direct system of lighting.

Point	Lamp A	Lamp B	Lamp C	Lamp D	Lamp E	Total	1.4 Total
a	.69	.28	.17	.045	.03	1.045	1.46
b	.62	.62	.24	.045	.045	1.56	2.20
c	.28	.69	.17	.03	.045	1.045	1.46
d	.69	.28	.45	.13	.07	1.49	2.08
e	.62	.62	.59	.115	.115	2.06	2.88
f	.28	.69	.45	.07	.13	1.49	2.08
g	.425	.425	.59	.14	.14	1.70	2.38
h	.35	.35	.725	.35	.35	2.125	2.97
i.	.14	.14	.59	.425	.425	1.70	2.38
k	.13	.07	.45	.61	.28	1.49	2.08
l	.115	.115	.59	.62	.62	2.06	2.80
m	.07	.13	.45	.28	.69	1.49	2.08
n.	.045	.03	.17	.69	.28	1.045	1.46
o	.045	.045	.24	.62	.62	1.57	2.20
p	.03	.045	.17	.28	.69	1.045	1.46
r	.50	.13	.12	.03	.02	.80	1.12
s.	.34	.11	.37	.34	.11	1.27	1.77
t	.62	.62	.13	.03	.03	1.13	2.00



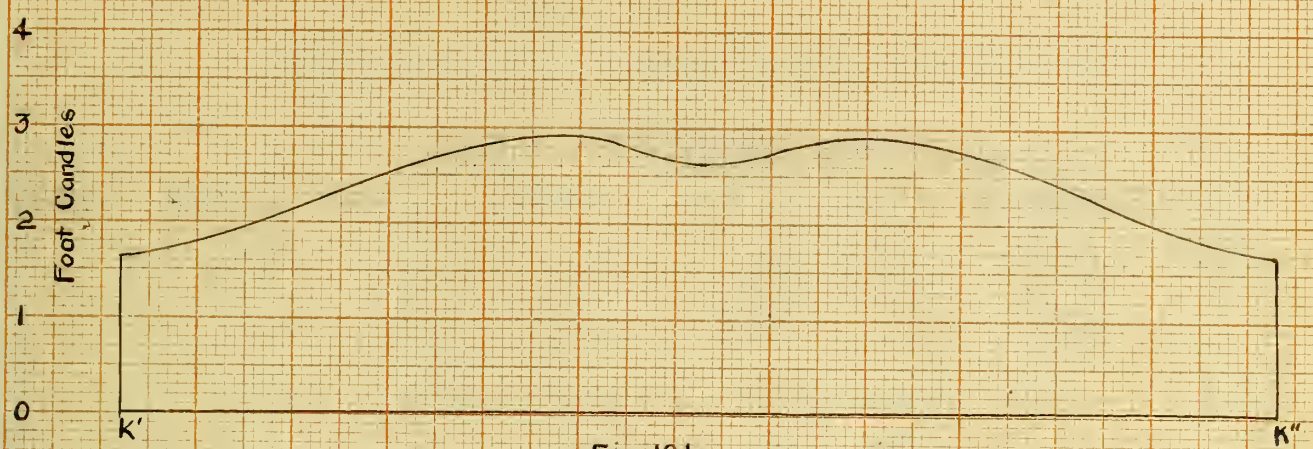


Fig 10b
Distribution of light along line K'K'' of Fig 10a
Horizontal Scale 1"=5'



Fig 10c
Distribution of light along line L'L'' of Fig 10a.

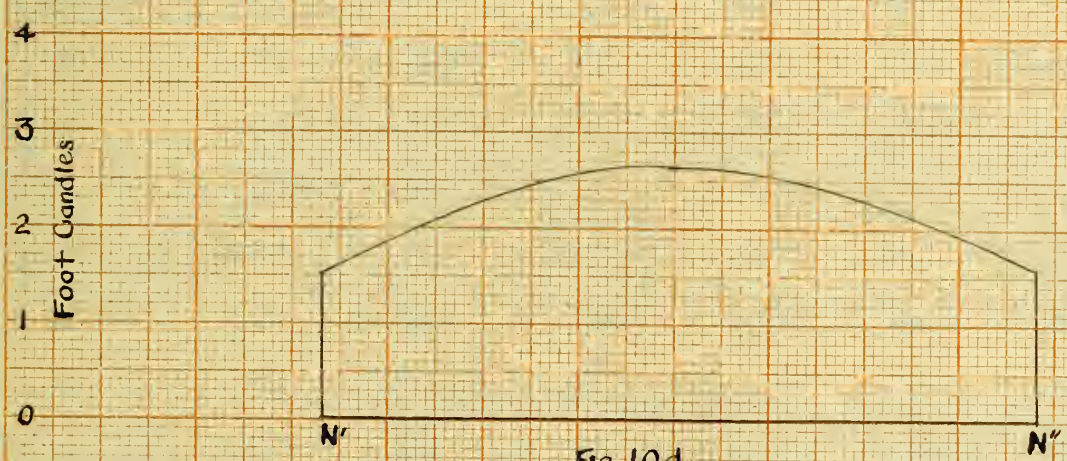


Fig 10d.
Distribution of light along line N'N'' of Fig 10a.

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1891
1892

TABLE No. 8

Illumination at various points of Room No. 3
for a direct system of lighting.

Point	Lamp A	Lamp B	Lamp C	Lamp D	Lamp E	Lamp F	1.4 Total
a	.65	.13	.12	.095	.02	.015	1.58
b	.665	.425	.115	.08	.02	.017	1.85
c	.425	.665	.08	.115	.017	.02	1.85
d	.13	.65	.095	.12	.015	.02	1.58
e	.66	.14	.39	.08	.04	.025	1.87
f	.665	.40	.40	.225	.04	.035	2.82
g	.40	.665	.225	.40	.035	.04	2.82
h	.14	.66	.08	.39	.023	.04	1.87
k	.40	.225	.67	.40	.125	.09	2.69
i	.39	.09	.65	.125	.125	.05	2.00
l	.225	.40	.40	.67	.09	.125	2.69
m	.09	.39	.125	.65	.125	.05	2.00
n	.125	.05	.65	.125	.39	.09	2.00
o	.125	.09	.67	.40	.40	.225	2.69
p	.09	.125	.40	.67	.225	.40	2.69
q	.05	.125	.125	.65	.09	.39	2.00
r.	.04	.025	.39	.08	.66	.14	1.87
s	.04	.035	.40	.225	.665	.40	2.82
t	.035	.04	.225	.40	.40	.665	2.82
u	.025	.04	.08	.39	.14	.66	1.87
v.	.02	.015	.12	.095	.65	.13	1.58
w	.02	.017	.115	.08	.665	.425	1.85
x	.017	.02	.08	.115	.425	.665	1.85
y	.015	.02	.095	.12	.13	.65	1.58

Table 1

1	2	3	4	5	6	7
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
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80	81	82	83	84	85	86
87	88	89	90	91	92	93
94	95	96	97	98	99	100
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227	228	229	230	231	232	233
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248	249	250	251	252	253	254
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773	774	775	776	777	778	779
780	781	782	783	784	785	786
787	788	789	790	791	792	793
794	795	796	797	798	799	800
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829	830	831	832	833	834	835
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843	844	845	846	847	848	849
850	851	852	853	854	855	856
857	858	859	860	861	862	863
864	865	866	867	868	869	870
871	872	873	874	875	876	877
878	879	880	881	882	883	884
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948	949	950	951	952	953	954
955	956	957	958	959	960	961
962	963	964	965	966	967	968
969	970	971	972	973	974	975
976	977	978	979	980	981	982
983	984	985	986	987	988	989
990	991	992	993	994	995	996
997	998	999	1000	1001	1002	1003
1004	1005	1006	1007	1008	1009	1010
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1361	1362	1363	1364	1365	1366	1367
1368	1369	1370	1371	1372	1373	1374
1375	1376	1377	1378	1379	1380	1381
1382	1383	1384	1385	1386	1387	1388
1389	1390	1391	1392	1393	1394	1395
1396	1397	1398	1399	1400	1401	1402
1403	1404					

- X A Lamp clusters (2-60 watt lamps each) Scale 1"=5'

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0 1 2 3 4 33
Foot Candles

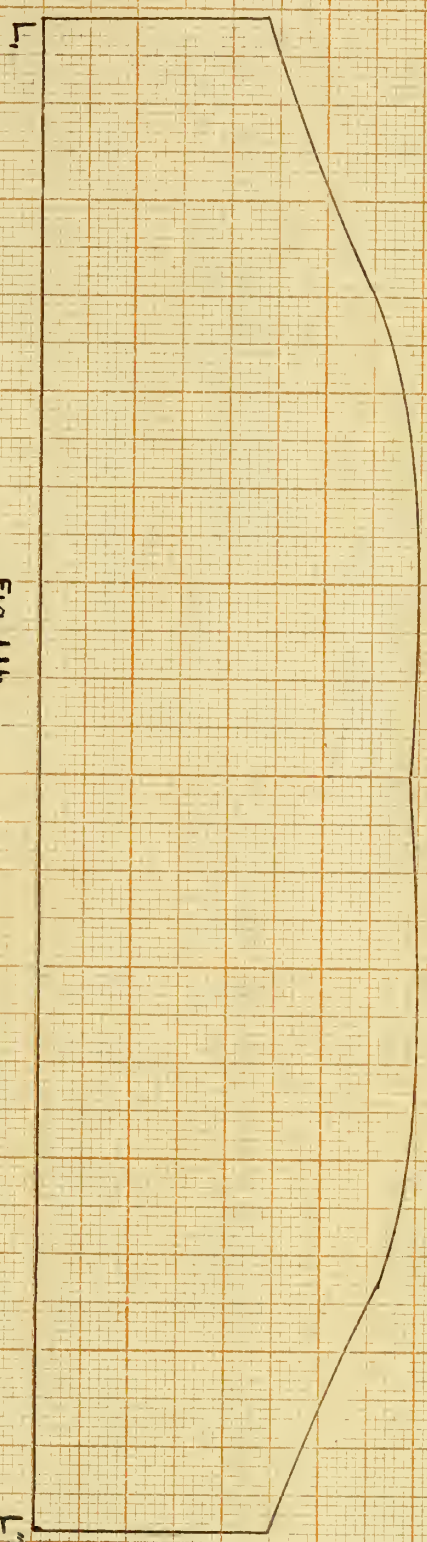


Fig 11b
Distribution of light along line L'L'' of Fig 11a
Horizontal Scale 1" = 5'

0 1 2 3 4
Foot Candles

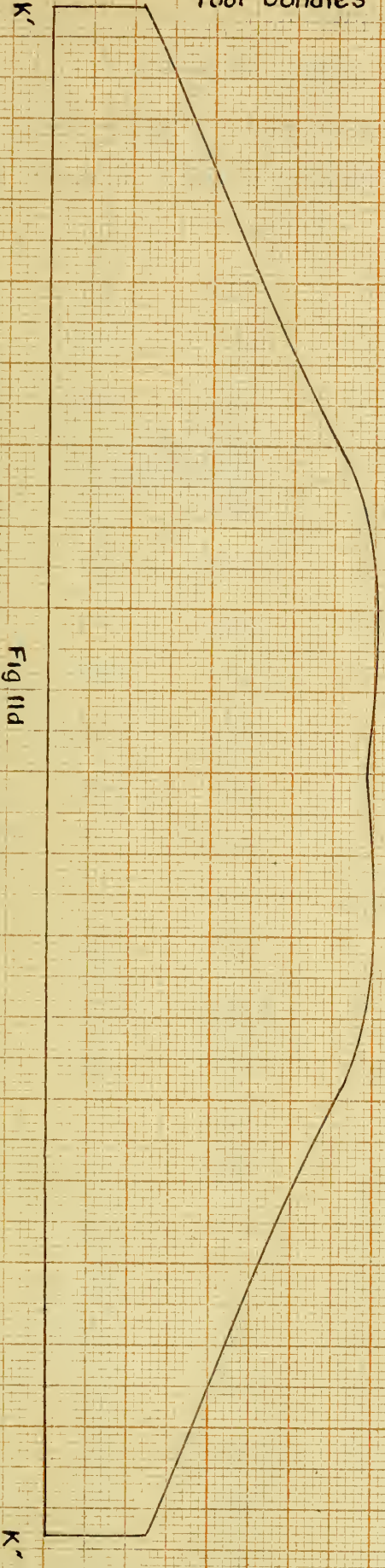


Fig 11d
Distribution of light along line K'K'' of Fig 11a

Wm. H. C. Co.
100 N. 3rd St.
St. Louis, Mo.

TABLE No. 9

Illumination at various points of Room No. 4
for a direct lighting system.

Point	Lamp A	Lamp B	Lamp C	Lamp D	Lamp E	Lamp F	1.4 Total
a	1.06	.11	.09	.035	.02	.01	1.85
b	1.28	.12	.21	.06	.03	.02	2.41
c	.92	.10	.70	.09	.05	.03	2.36
d	.40	.07	1.18	.29	.29	.04	3.18
e	.29	.04	1.18	.29	.40	.07	3.18
f	.05	.03	.70	.09	.92	.10	2.36
g	.03	.02	.21	.06	1.28	.12	2.41
h	.02	.01	.09	.035	1.06	.11	1.85
i	1.28	.35	.09	.06	.01	.01	2.52
k	1.44	.40	.26	.11	.06	.025	3.20
l	1.10	.28	.85	.22	.06	.04	3.57
m	.41	.14	1.36	.37	.14	.07	3.48
n	.14	.07	1.36	.37	.41	.14	3.48
o	.06	.04	.85	.22	1.10	.28	3.57
p	.06	.025	.26	.11	1.44	.40	3.20
q	.01	.01	.09	.06	1.28	.35	2.52
r	.89	.89	.08	.08	.02	.02	2.77
s	1.06	1.06	.19	.19	.03	.03	3.58
t	.75	.75	.55	.55	.05	.05	3.78
u	.28	.28	1.00	1.00	.11	.11	3.90
v	.11	.11	1.00	1.00	.28	.28	3.90
w	.05	.05	.55	.55	.75	.75	3.78
x.	.03	.03	.19	.19	1.06	1.06	3.58
y	.02	.02	.08	.08	.89	.89	2.77
z	.35	1.28	.06	.09	.01.	.01	2.52

TABLE No. 9(concluded)

Point	Lamp A	Lamp B	Lamp C	Lamp D	Lamp E	Lamp F	1.4 Tot.
aa	.40	1.44	.11	.26	.025	.06	3.20
bb	.28	1.10	.22	.85	.04	.06	3.57
cc	.14	.41	.37	1.36	.07	.14	3.48
dd	.07	.14	.37	1.36	.14	.41	3.48
ee	.04	.06	.22	.85	.28	1.10	3.57
ff	.025	.06	.11	.26	.40	1.44	3.20
gg	.01	.01	.06	.09	.35	1.28	2.52
hh	.11	1.06	.035	.09	.01	.02	1.85
ii	.12	1.28	.06	.21	.02	.03	2.41
kk	.10	.92	.09	.70	.03	.05	2.36
ll	.07	.40	.29	1.28	.04	.29	3.18
mm.	.04	.29	.29	1.18	.07	.40	3.18
oo	.03	.05	.09	.70	.10	.92	2.36
pp	..02	.03	.06	.21	.12	1.28	2.41

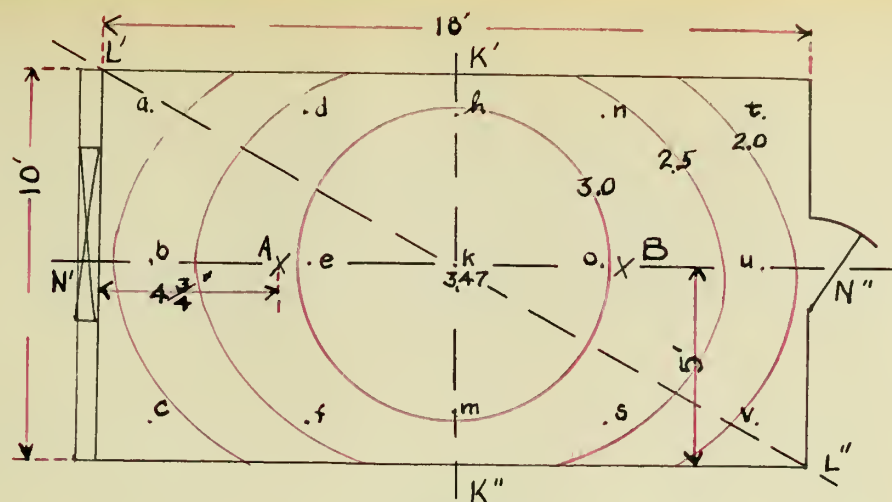


Fig. 12a

Direct lighting distribution for Room No. 5

• a) Points for which illumination was calculated
• b)

X A Lamp clusters (2-60 watt lamps each)

Scale 1" = 5'

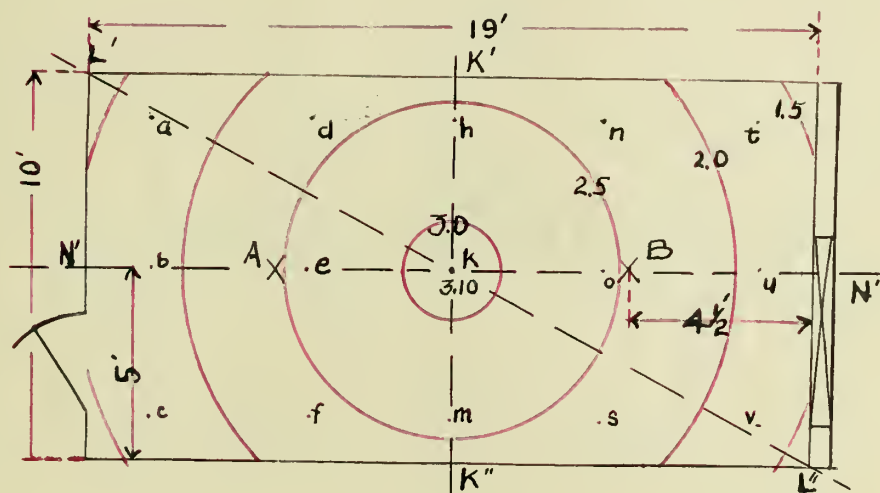


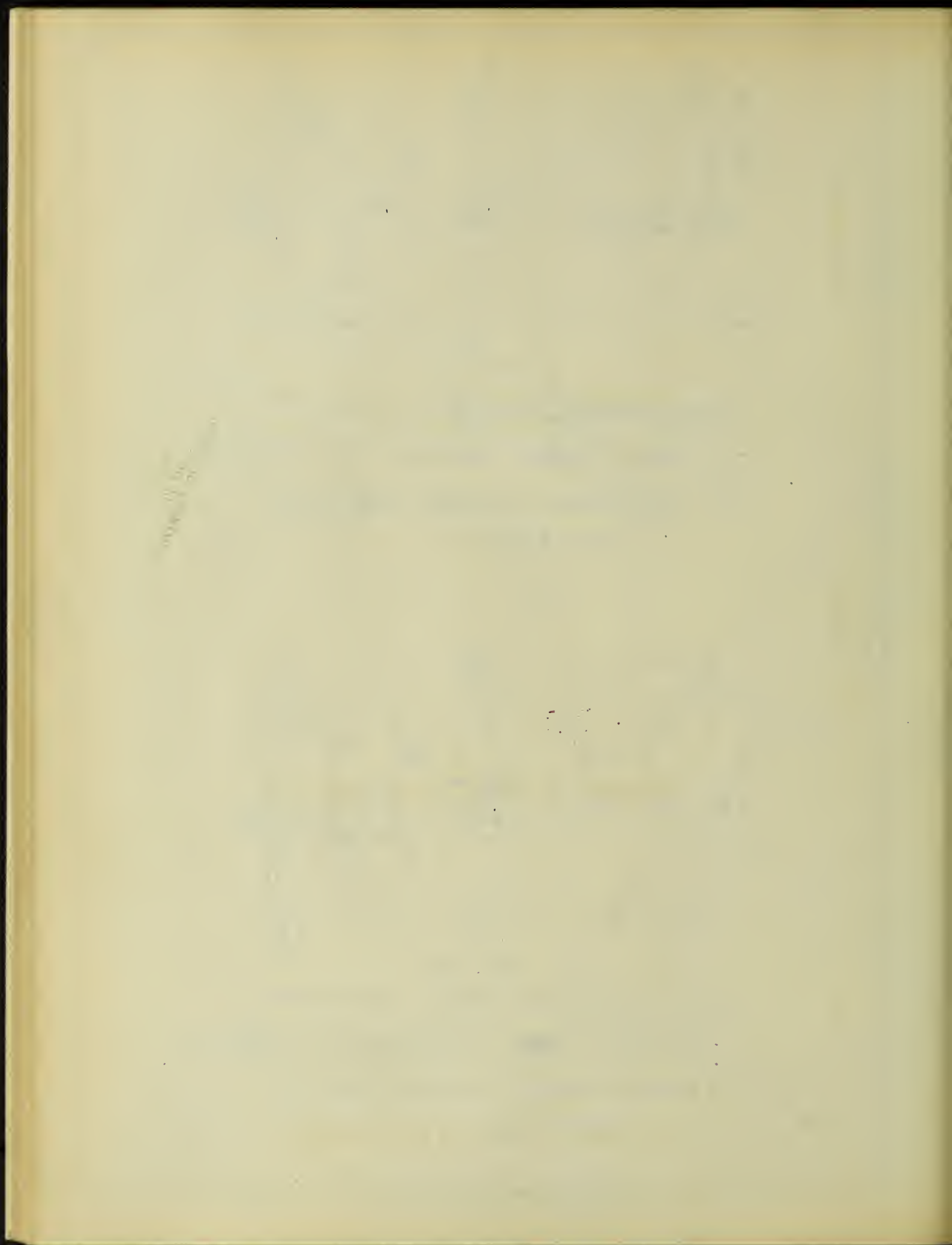
Fig. 13a

Direct lighting distribution for Room No. 6

• a) Points for which illumination was calculated
• b)

X A Lamp clusters (3-40 watt lamps each)

Scale 1" = 5'



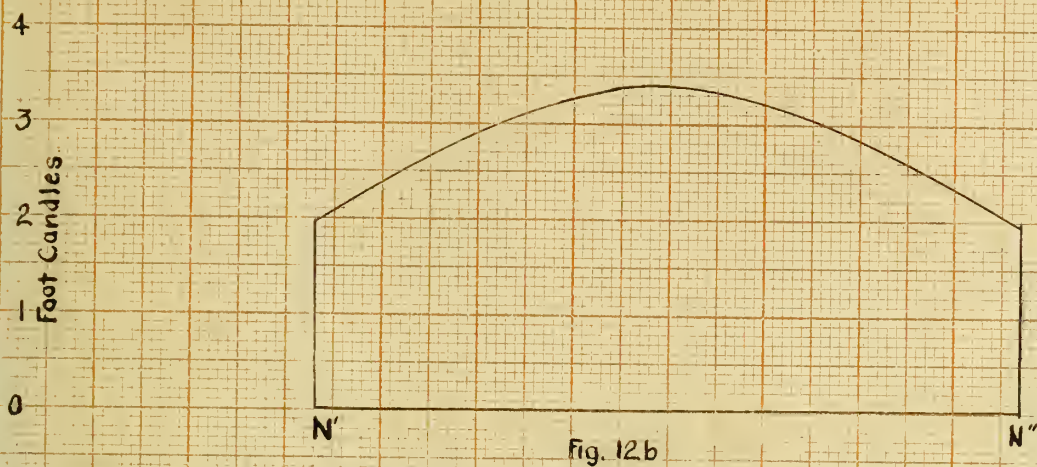


Fig. 12b

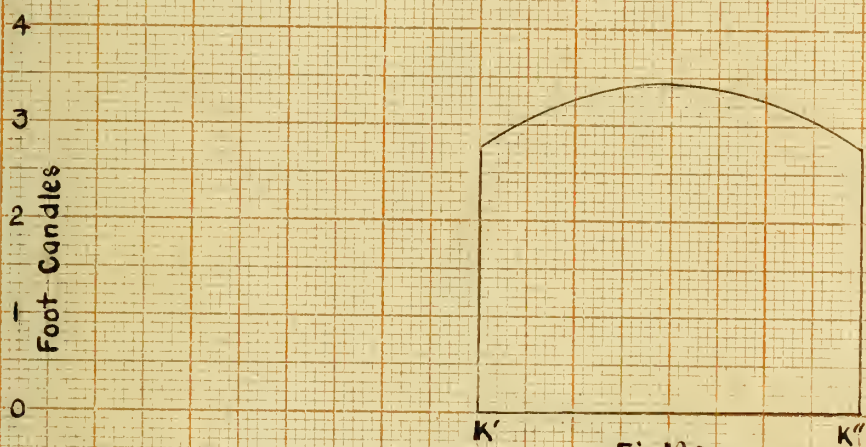
Distribution of light along line $N'N''$ of Fig 12aHorizontal scale $1''=5'$ 

Fig 12c

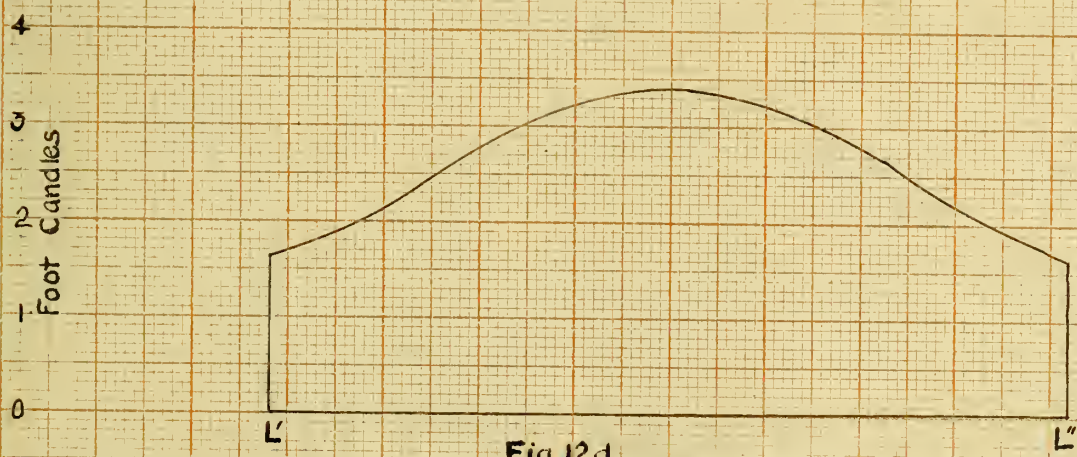
Distribution of light along line $K'K''$ of Fig 12a

Fig 12d

Distribution of light along line $L'L''$ of Fig 12a

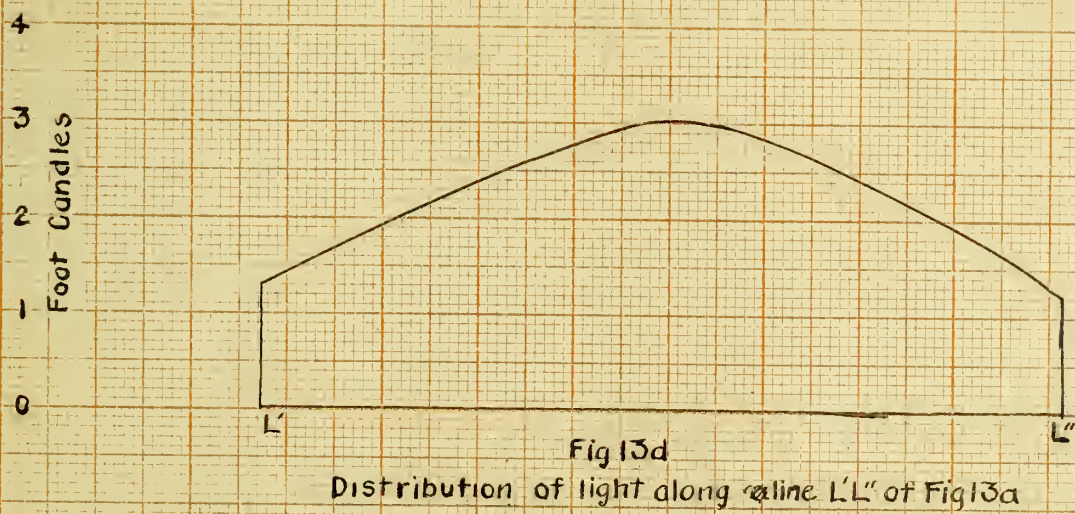
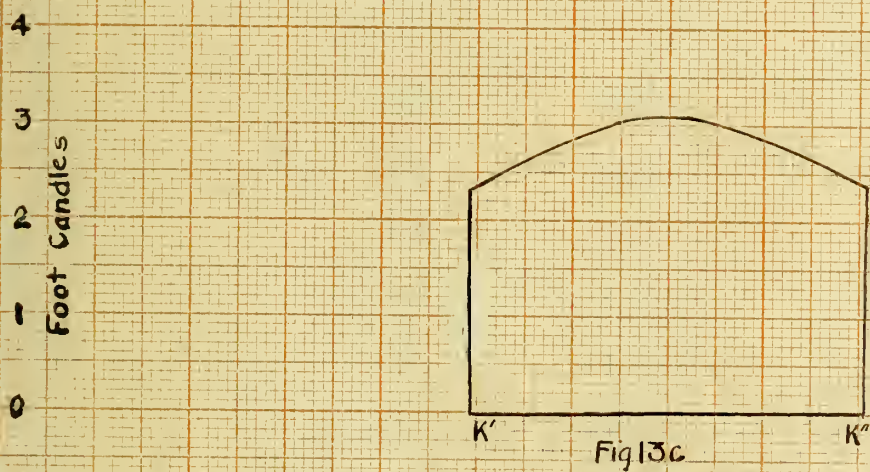
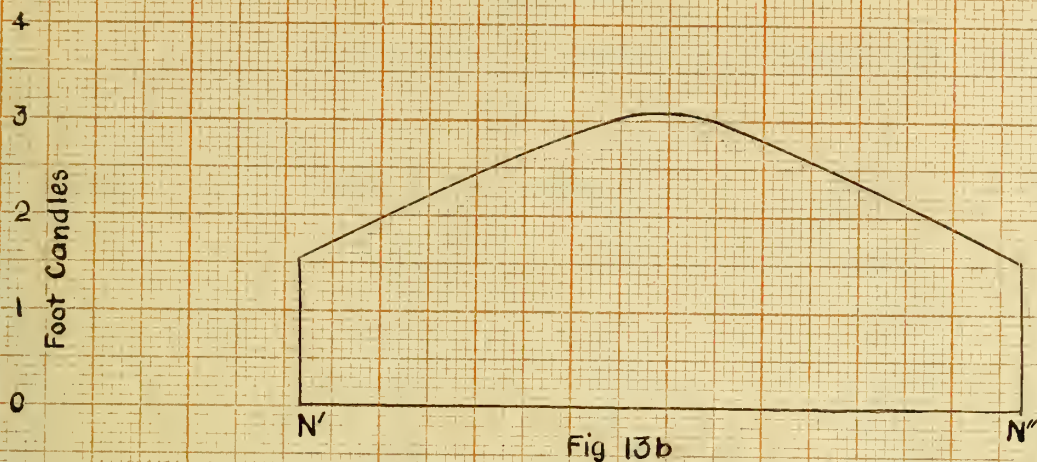
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TABLE No. 10

Illumination at various points of Room No.5
for a direct lighting system.

Point	Lamp A	Lamp B	Total	1.4 Total
a	1.14	.23	1.37	1.92
b	1.33	.28	1.51	2.25
c	1.14	.23	1.37	1.92
d	1.28	.60	1.88	2.63
e	1.44	.72	2.16	3.02
f	1.28	.60	1.88	2.63
h	1.08	1.08	2.16	3.02
k	1.24	1.24	2.48	3.47
m	1.08	1.08	2.16	3.02
n	.60	1.28	1.88	2.63
o	.72	1.44	2.16	3.02
s	.60	1.28	1.88	2.63
t	.23	1.14	1.37	1.92
u	.28	1.33	1.51	2.25
v	.23	1.14	1.37	1.92

TABLE No. 11

Illumination at various points of Room No.6
for a direct system of lighting.

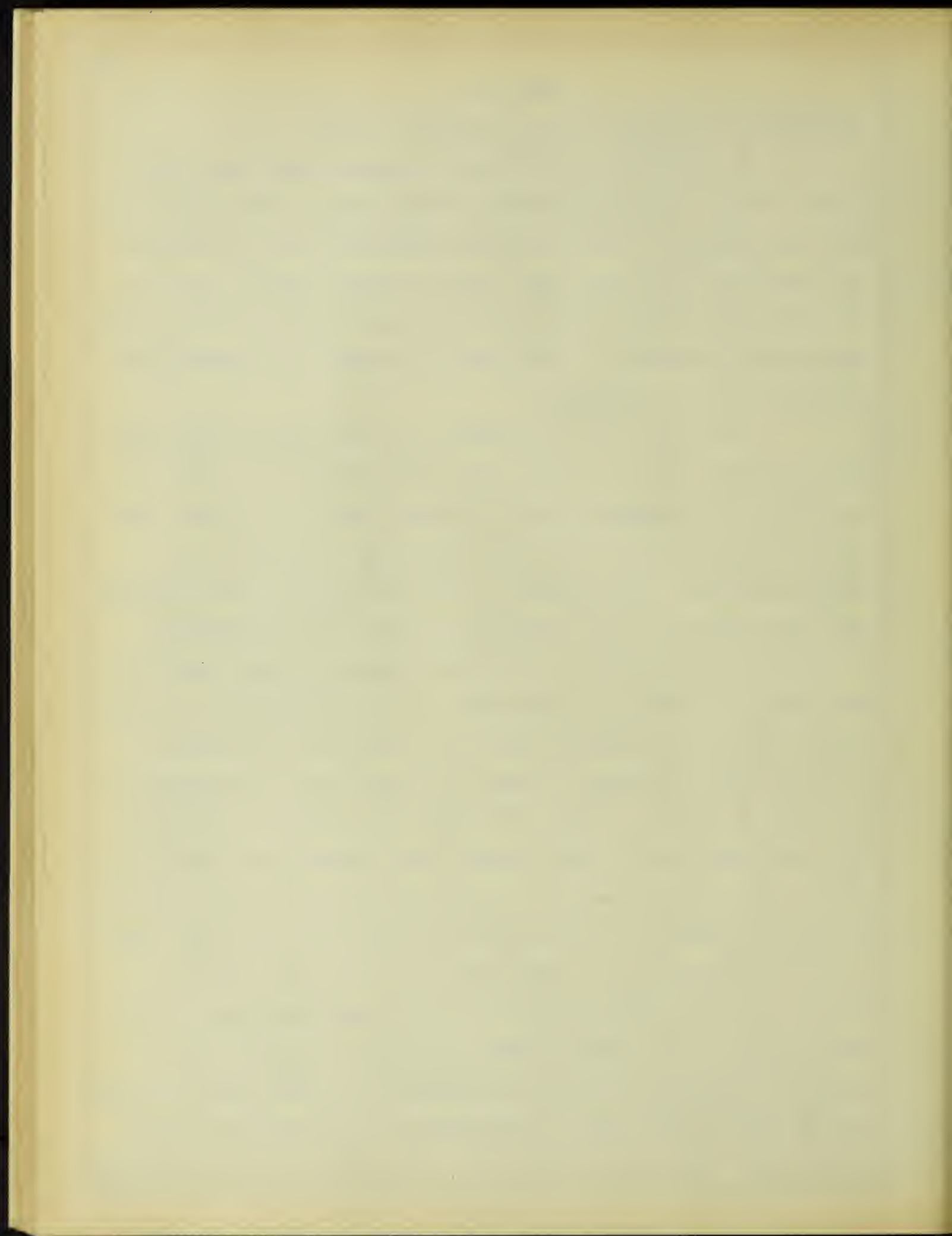
Point	Lamp A	Lamp B	Total	1.4 Total
a	1.03	.195	1.225	1.72
b	1.17	.225	1.395	1.96
c	1.03	.195	1.225	1.72
d	1.14	.48	1.62	2.27
e	1.43	.615	2.045	2.86
f	1.14	.48	1.62	2.27
h	.93	.93	1.86	2.62
k	1.11	1.11	2.22	3.10
m	.93	.93	1.86	2.62
n	.48	1.14	1.62	2.27
o	.615	1.43	2.045	2.86
s	.48	1.14	1.62	2.27
t	.195	1.03	1.225	1.72
u	.225	1.17	1.395	1.96
v	.195	1.03	1.225	1.72

Part II.

Measurement for Present Indirect Lighting System.

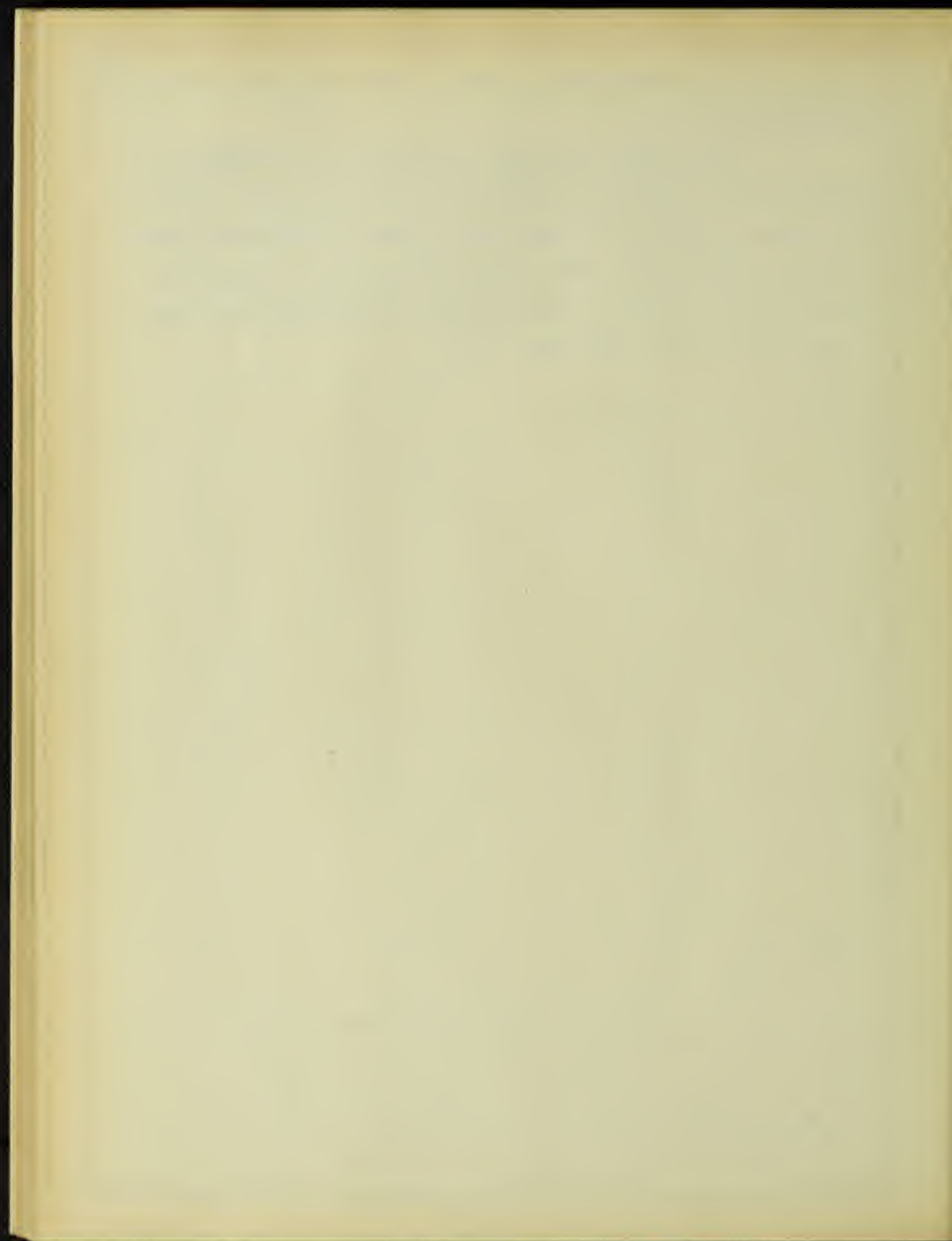
As the rooms for which the illumination has been calculated in Part I. are lighted by the indirect method, the illumination at various points of these rooms was measured in order to compare the distribution of light under the two methods. Tables 12 to 17 inclusive show the illumination at these various points. These values were measured directly in foot candles by means of a Sharp-Millar Portable Universal Photometer.

The body of this instrument is a hard wood box about two feet in length, having a hinge cover. The movable part of the photometer is a comparison lamp (4 candle power at 96 volts). The lamp is mounted inside of a metal housing and is carried on a movable platform. This platform is moved by means of a cord and drum. The scale from which the indications are read is a translucent celluloid one and is set in a horizontal opening in the side of the box. In order to keep out stray light it can be covered with a metal slide. This scale is illuminated by the test lamp. The inside of the box is painted black in order to cut down the stray deflections of light. In addition to this there are three screens between the lamp and lenses for the same purpose. These screens are connected to the lamp stands by means of cords and are mounted on two rails running the length of the box. They are connected to the lamp stand in such a way that as the lamp advances it pushes them before it and as it retreats pulls them with it. The photometric device is a modification of the Lummer-Brodhun arrangement. By means of the movable elbow tube at the end of the box, light coming from any plane may be measured. The scale is calibrated to read directly to foot candles thus saving many calculations. Fig. 14 shows a side elevation



and a plan of the photometer, giving a good idea of the proportions of each part.

As has been said before the amount of illumination of each room was measured at various places and the results plotted in figures 15a, 16a, 17a, 18a, 19a, and 20a, as those for direct lighting were plotted. From these drawings curves showing the distribution of light in various parts of the rooms were drawn (see Fig. 15b, 15c, 15d, 16a, etc.).



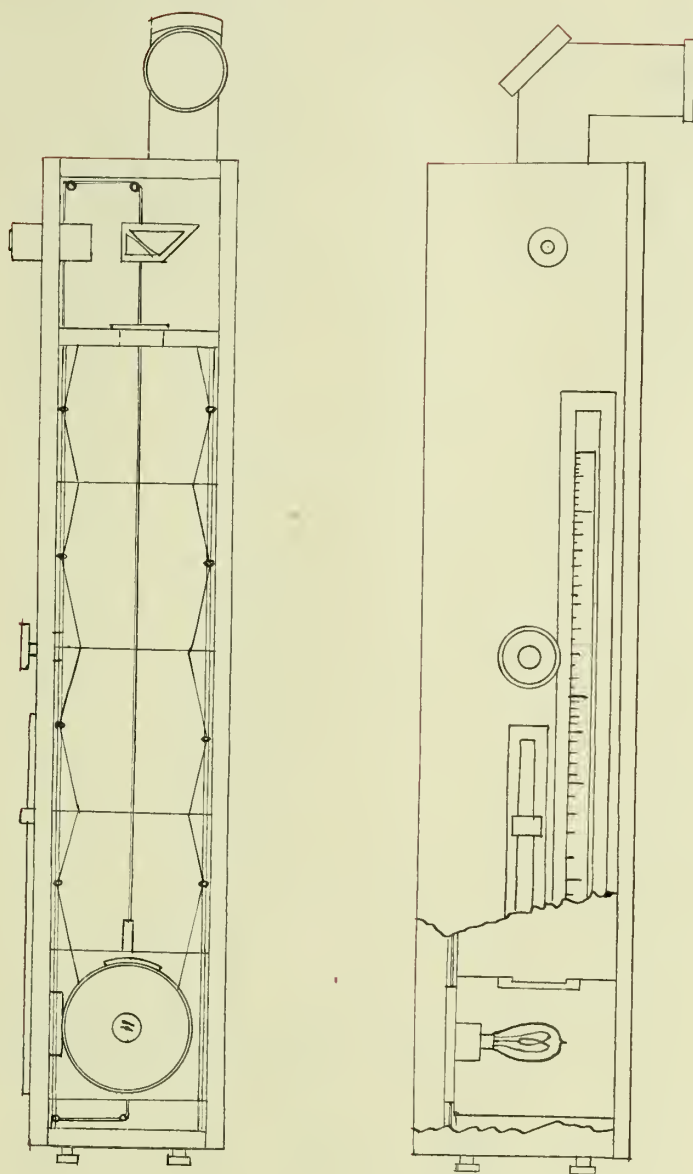
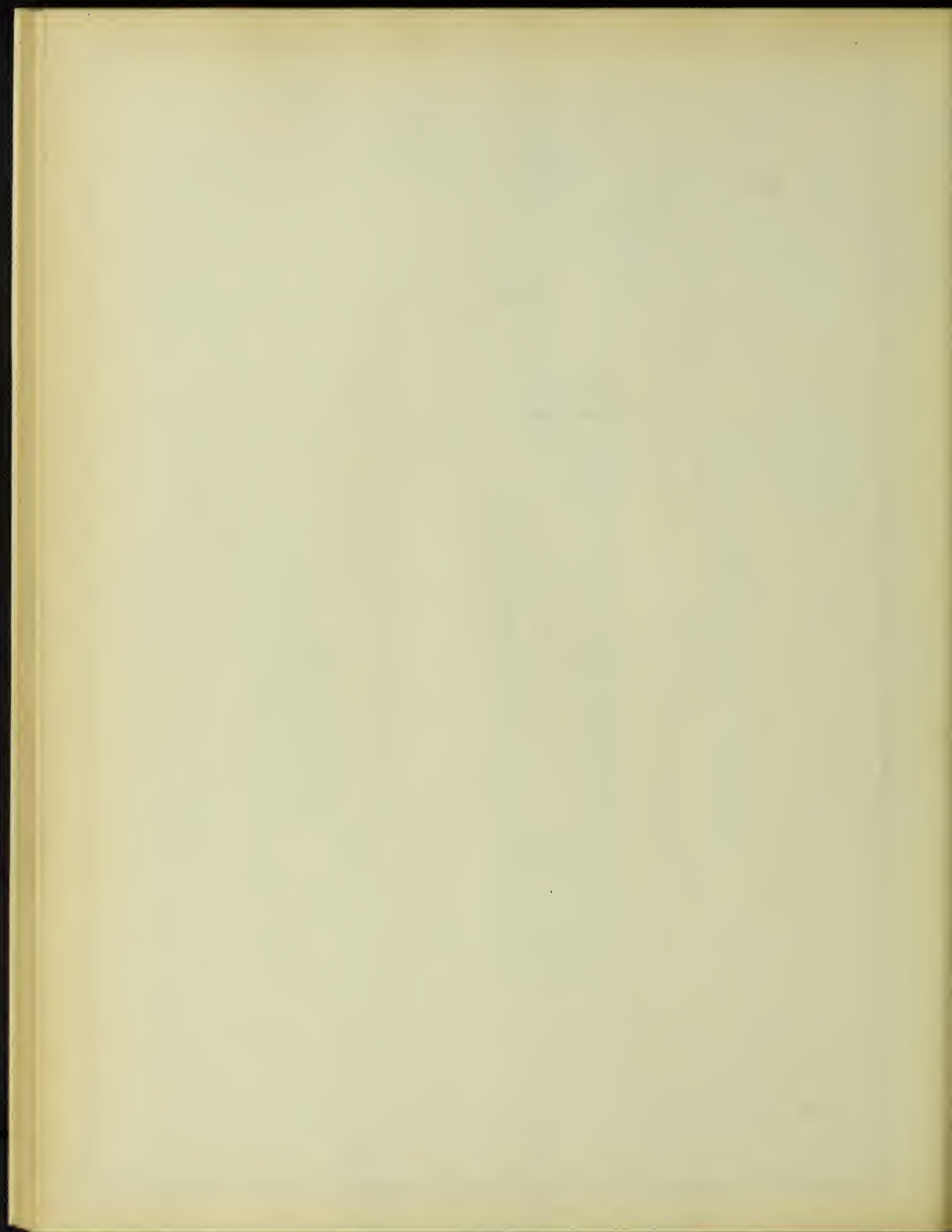


Fig. 14

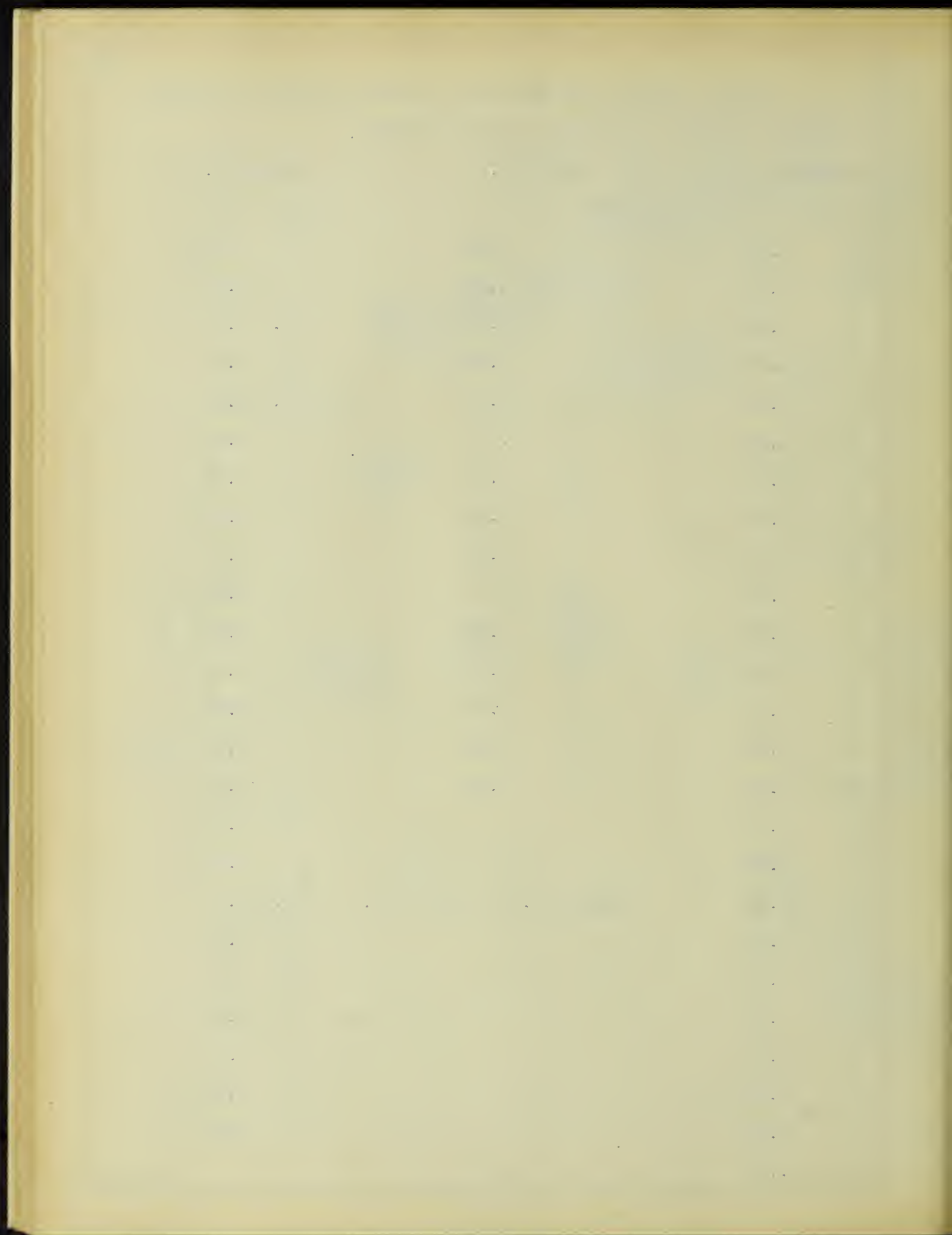
Side elevation and plan of Photometer



Tables showing illumination at various points of Rooms

No. 1, 2,&3 for the present indirect system.

Room No.1		Room No.2		Room No.3	
Point	E	Point	E	Point	E
a	2.02	a	2.02	a	2.38
b	1.65	b	1.65	b	2.84
c	1.52	c	1.03	c	2.80
d	1.23	d	2.30	d	1.90
e	1.15	e	2.04	e	2.30
f	1.48	f	1.48	f	2.98
g	1.75	g	2.26	g	2.90
h	1.92	h	2.10	h	2.60
i	1.91	i	1.98	i	2.41
k	1.77	k	1.4	k	3.30
l	1.42	l	1.97	l	3.10
m	1.95	m	2.1	m	3.02
n	2.15	n	1.00	n	2.18
o	2.08	o	1.30	o	3.20
p	2.01	p	1.38	p	3.20
q	1.15			q	2.30
r	1.89			r	2.04
s	1.99	TABLES No. 12, 13, & 14.		s	2.60
t	2.02			t	2.50
u	2.00			u	1.64
v	.79			v	1.57
w	1.42			w	2.10
x	1.33			x	1.46
y	1.35			y	1.00
z	1.38				



Tables showing illumination at various points of
Rooms No. 4,5,&6 for the present indirect system.

Room No.4				Room No.5		Room No.6	
Point	E	Point	E	Point	E	Point	E
a	1.17	aa	1.07	a	1.52	a	1.94
b	1.46	bb	1.10	b	1.85	b	2.08
c	1.92	cc	1.54	c	1.87	c	1.23
d	2.20	dd	1.53	d	1.33	d	.82
e	2.10	ee	.74	f	2.16	e	1.98
f	2.00	ff	1.32	e	1.83	f	2.05
g	1.95	gg	1.46	g	1.70	g	1.23
h	1.55	hh	1.87	h	1.40	h	.59
i	1.52	ii	.71	i	1.80	i	1.64
k	2.00	kk	.60	k	1.80	k	1.80
l	2.48	ll	.99	l	1.54	l	1.30
m	2.20	mm	1.10	m	1.10	m	.56
n	2.20	nn	.63				
o	2.32	oo	.54				
p	2.00	pp	.86				
q	1.68						
r	2.01						
s	2.00						
t	2.32						
u	2.45						
v	2.34						
w	2.56						
x	2.24						
y	1.88						
z	1.28						

TABLES No. 15, 16, & 17.

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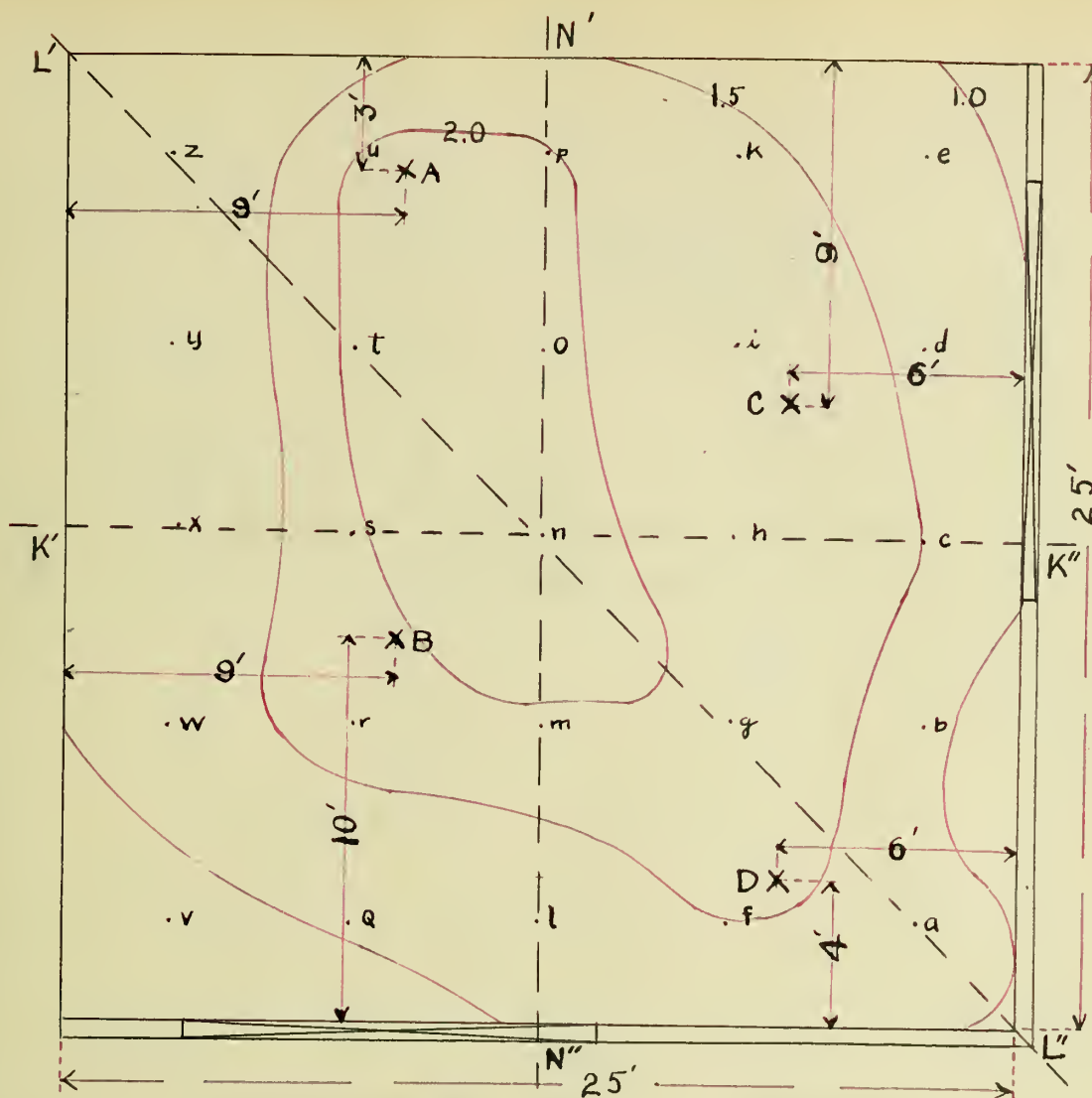


Fig. 15a

Indirect lighting distribution for Room No.1

• a) Points at which illumination was measured

X A Lamp clusters (2-100 watt lamps each)

Scale 1" = 5'

11

THE HISTORY OF THE
CITY OF BOSTON

FROM THE FIRST SETTLEMENT
TO THE PRESENT TIME

BY
JOHN H. COLEMAN

3
2
1
0
Foot Candles



Fig 15b

Distribution of light along line K'K'' of Fig 15a.
Horizontal Scale 1" = 5'.

3
2
1
0
Foot Candles



Fig 15c

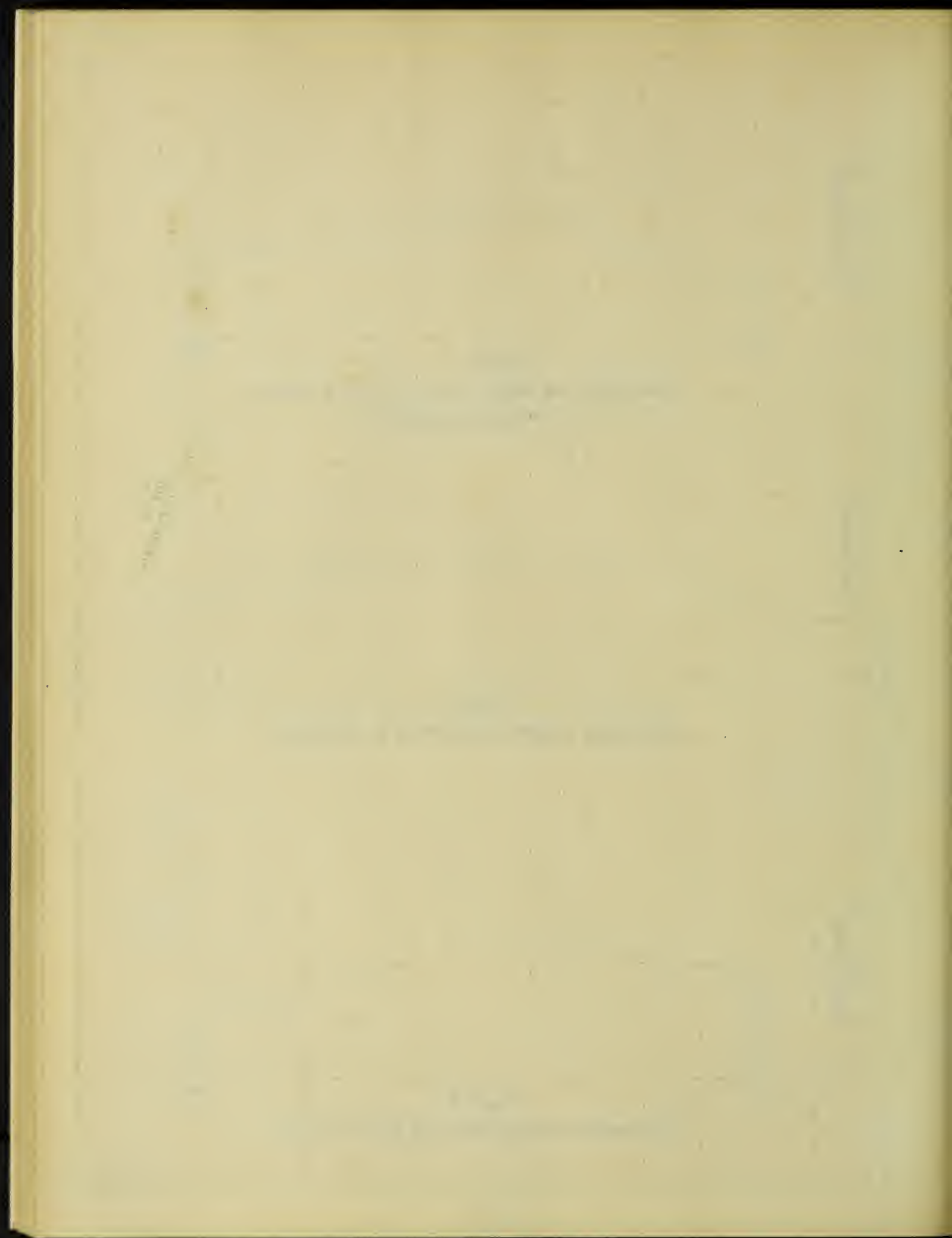
Distribution of light along line L'L'' of Fig 15a.

3
2
1
0
Foot Candles



Fig 15d

Distribution of light along line N'N'' of Fig 15a.



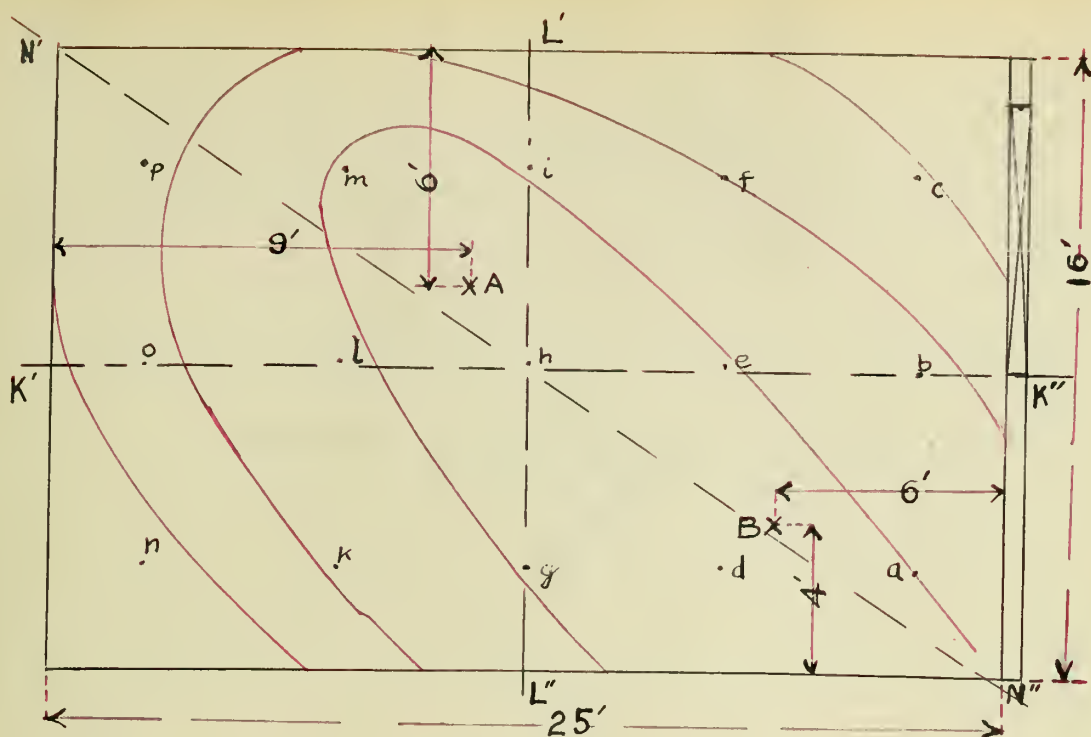


Fig. 16a

Indirect lighting distribution for Room No.2

- a)
 - b) Points at which illumination was measured
- X A Lamp clusters (2-100 watt lamps each)

Scale 1" = 5'

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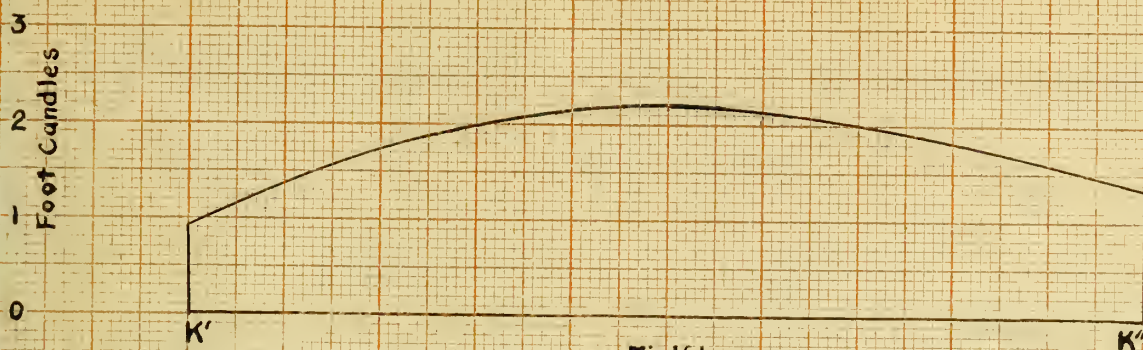


Fig 16b

Distribution of light along line K'K'' of Fig 16a.
Horizontal Scale 1" = 5'

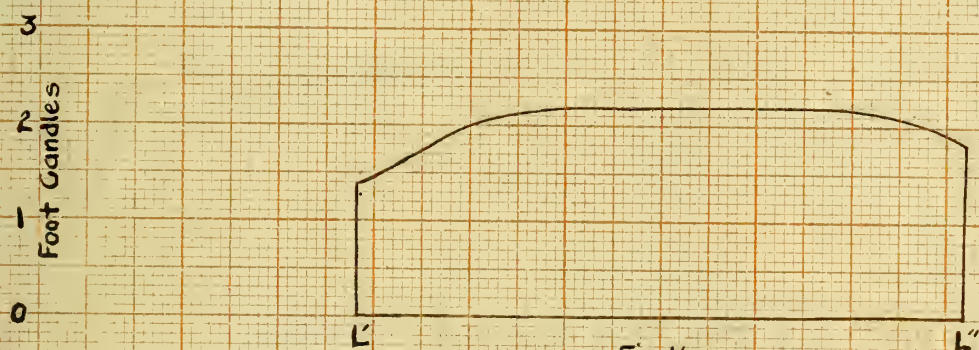


Fig 16c

Distribution of light along line L'L'' of Fig 16a.



Fig 16d

Distribution of light along line N'N'' of Fig 16a

100
100
100

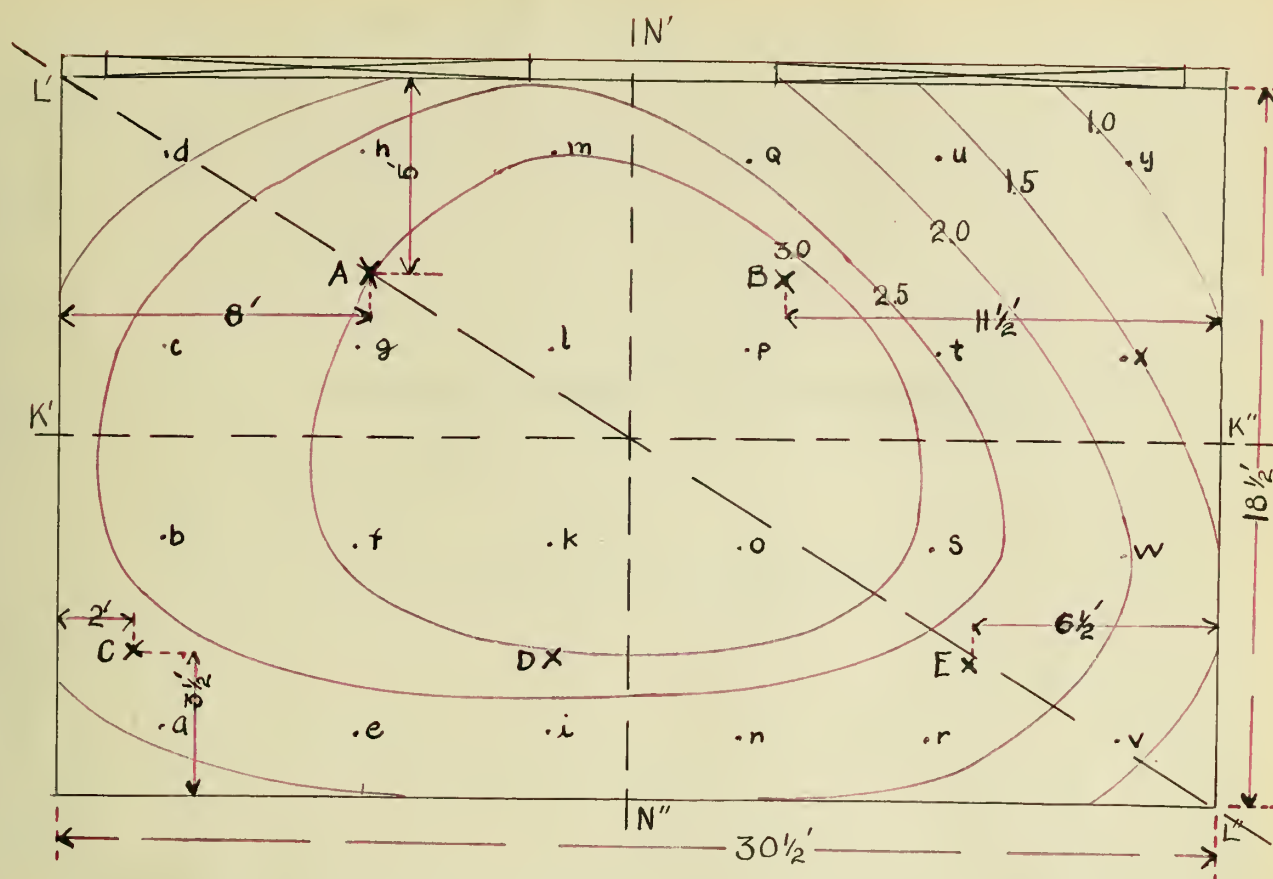


Fig. 17a

Indirect lighting distribution for Room No.3

- a) Points at which illumination was measured
- b) Points at which illumination was measured
- X A Lamp clusters (2-100 watt lamps each)

Scale 1"= 5'

THE UNIVERSITY OF CHICAGO

PHYSICS DEPARTMENT

REPORT OF THE

COMMISSIONERS OF THE

BOARD OF PHYSICS

FOR THE YEAR 1887

CHICAGO, ILL.

1888

Foot Candles

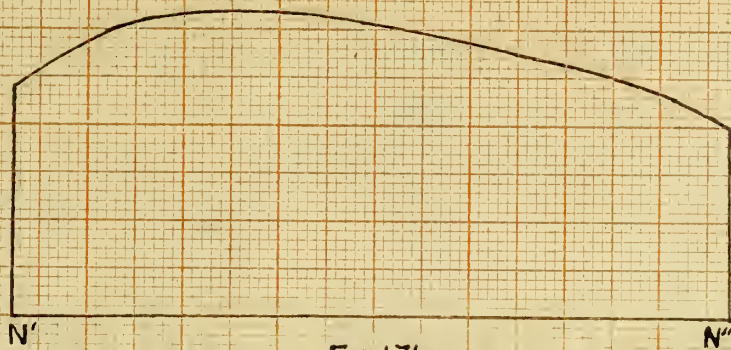


Fig 17b

Distribution of light along line $N'N''$ of Fig 17a

Foot Candles



Fig 17c

Distribution of light along line $K'K''$ of Fig 17a

Foot Candles

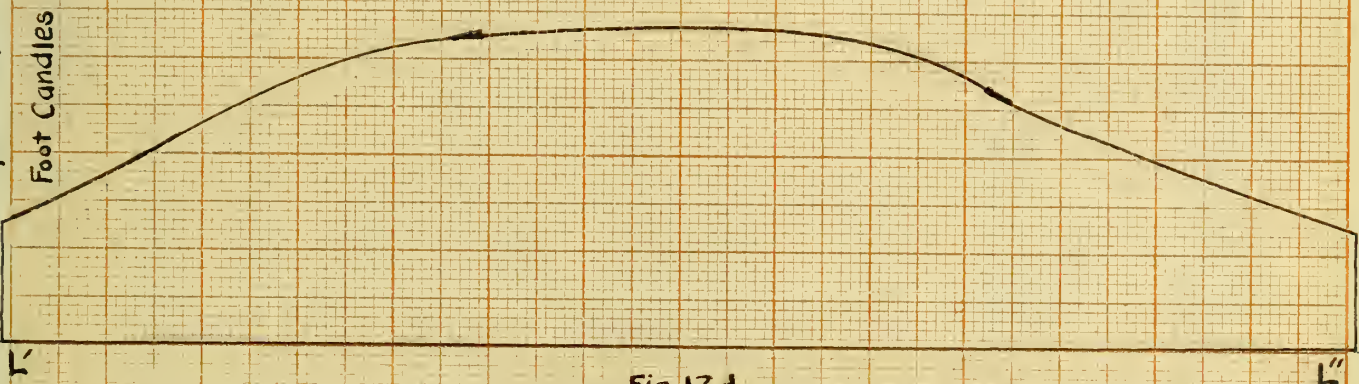


Fig 17d

Distribution of light along line $L'L''$ of Fig 17a
Horizontal Scale $1''=5'$

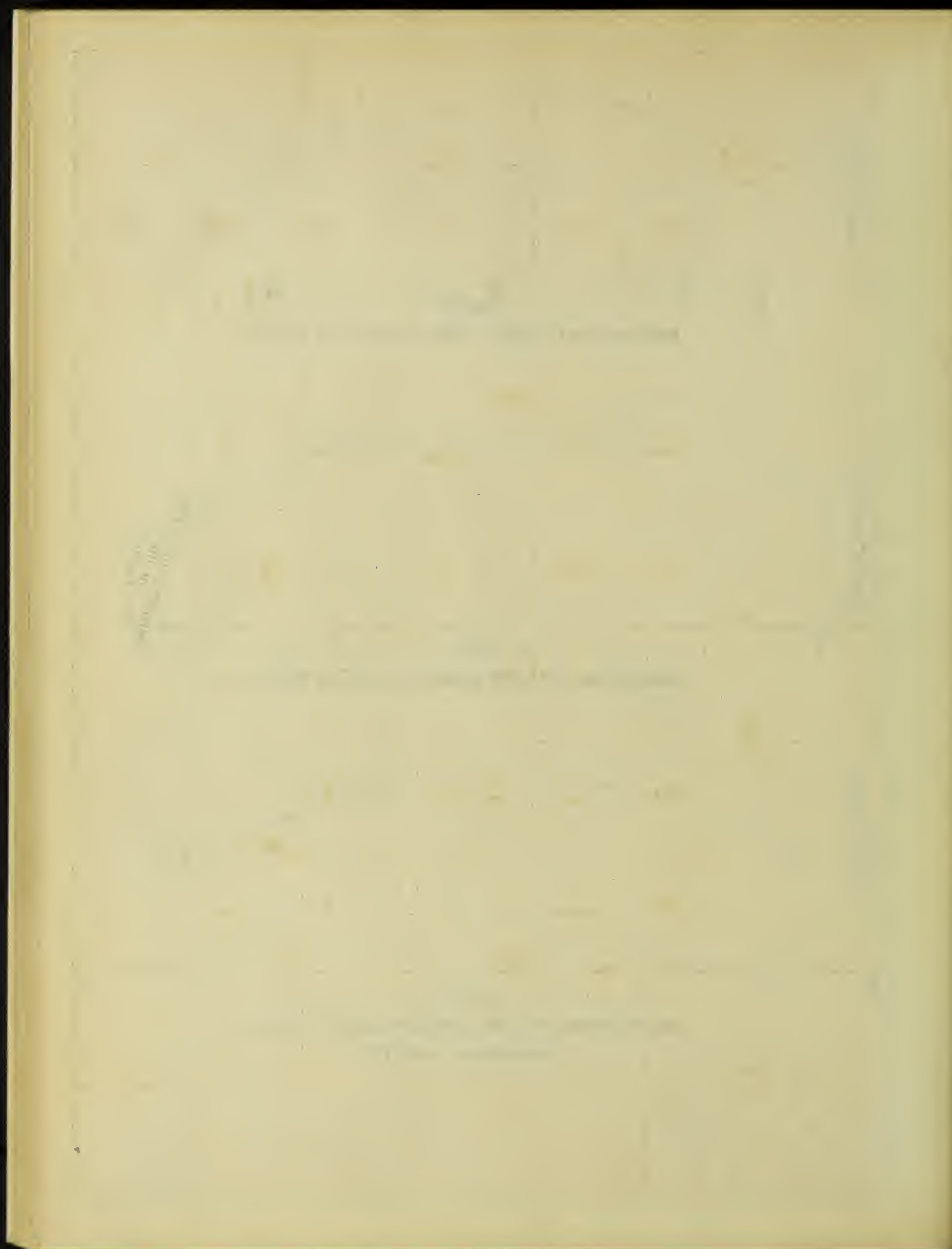
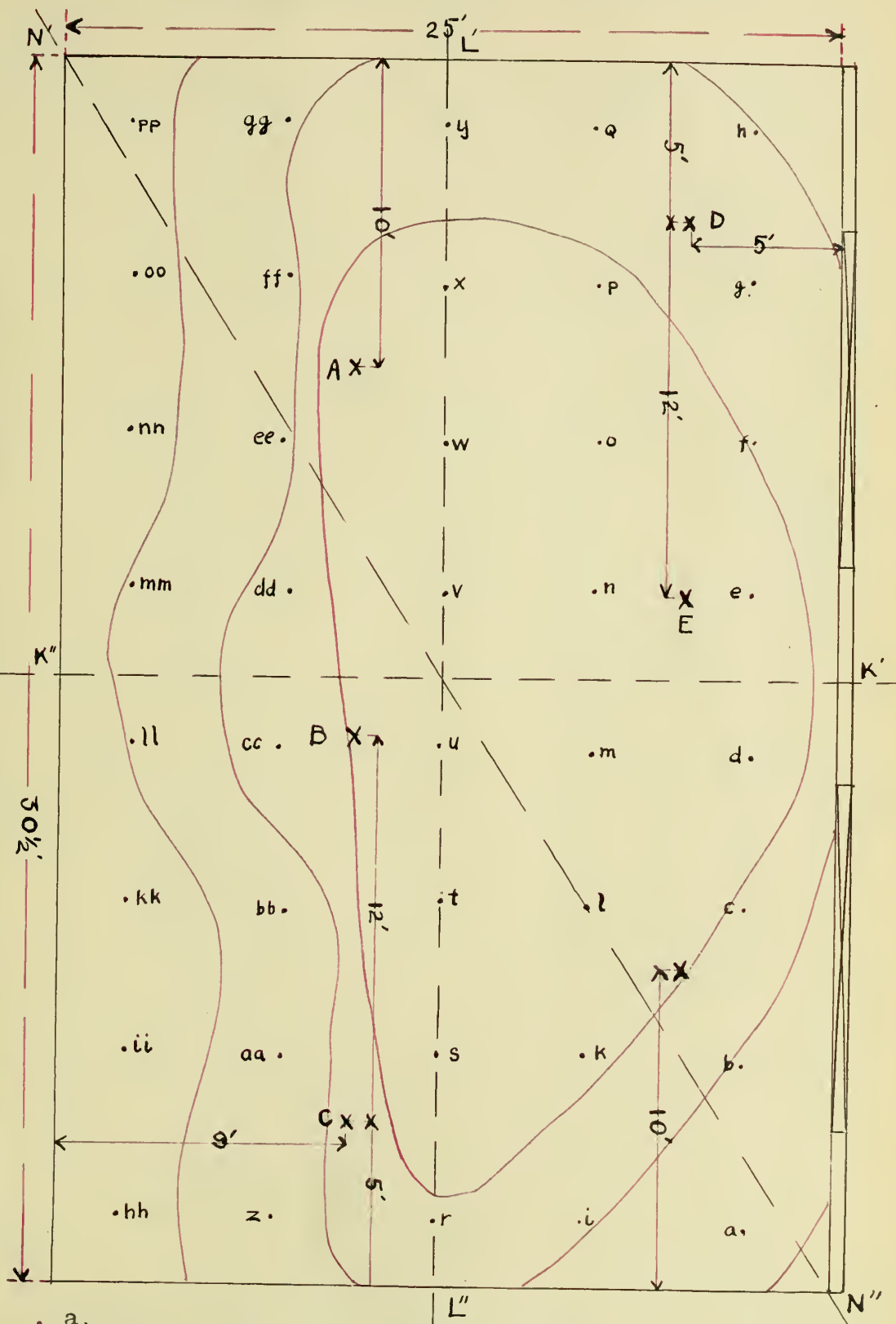


Fig. 18a

Indirect lighting distribution for Room No.4

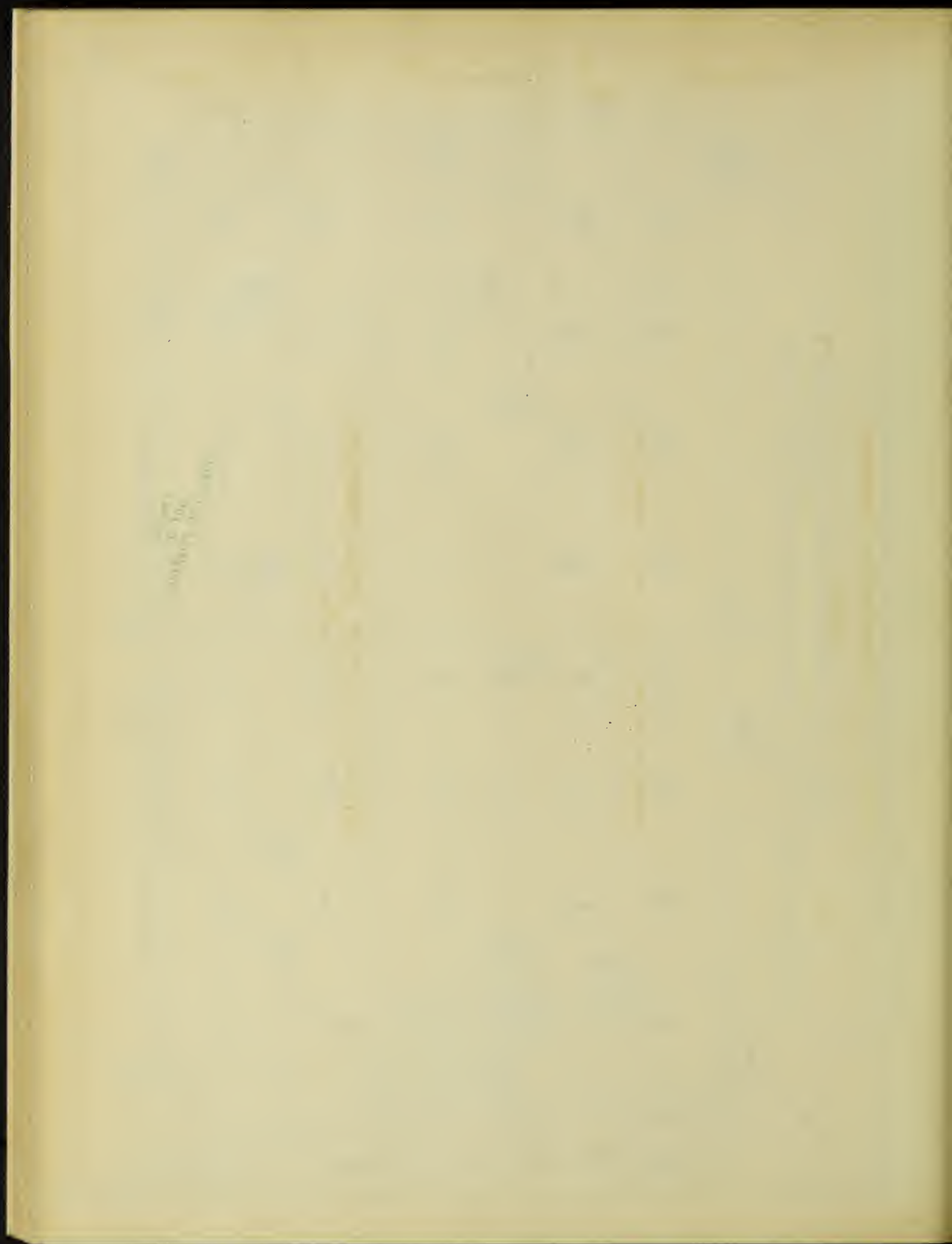
Note - The light was poor at this side of the room because of the book stacks which are about 8 ft. high.



a) Points at which illumination was measured

X A Lamp clusters (2-100 watt lamps)

Scale 1" = 5'



53
Foot Candles



Fig 18b
Distribution of light along line $L'L'$ of Fig 18a.

Foot Candles

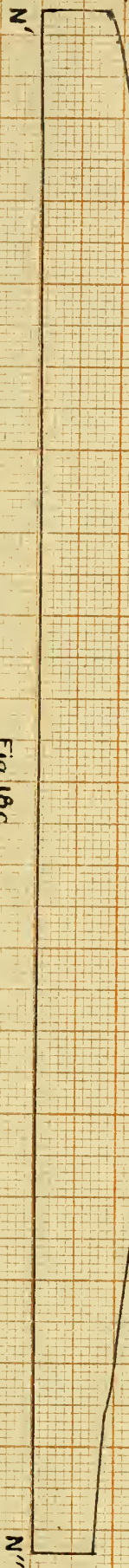
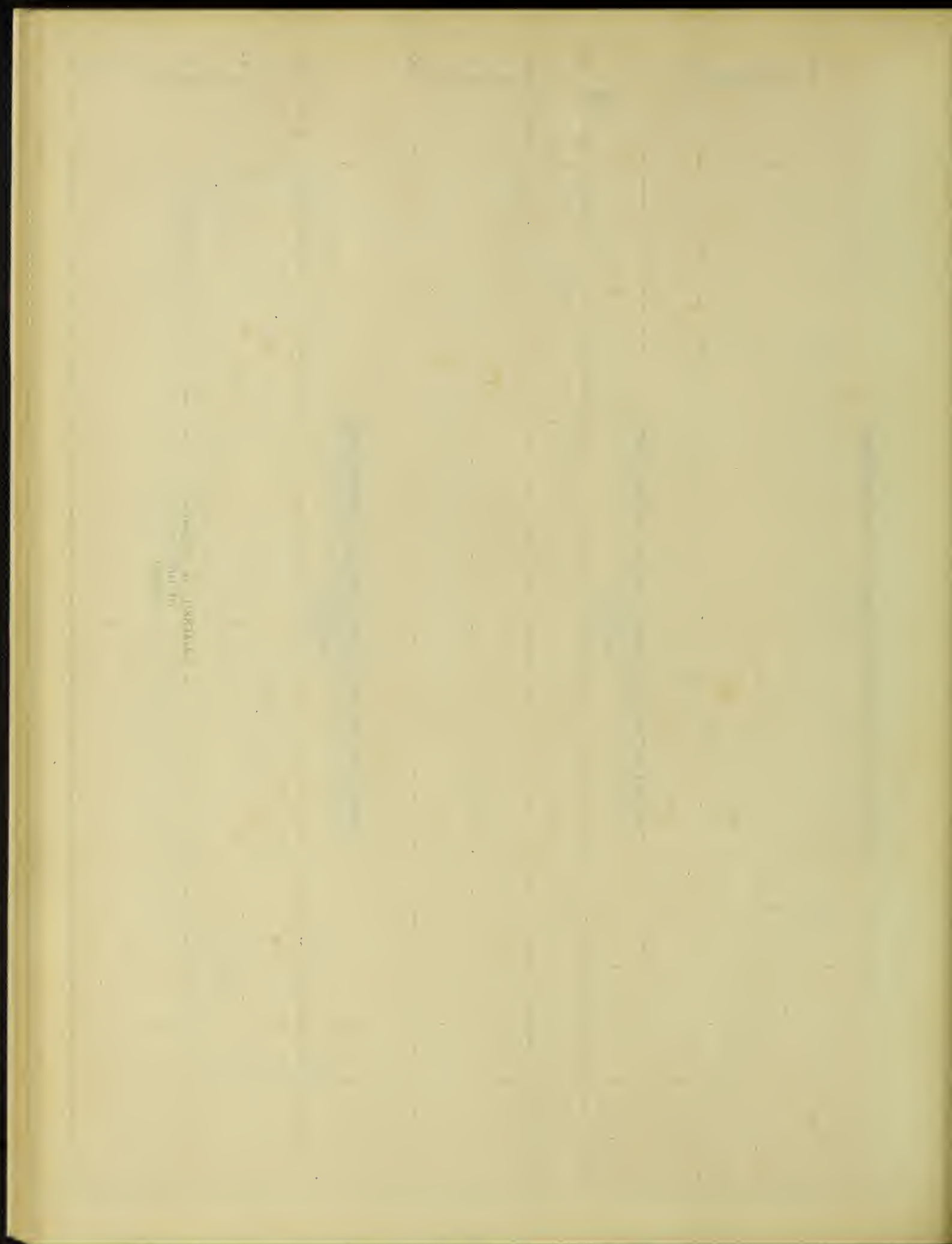


Fig 18c
Distribution of light along line $N'N''$ of Fig 18a

Foot Candles



Fig 18d
Distribution of light along line $K''K'$ of Fig 18a



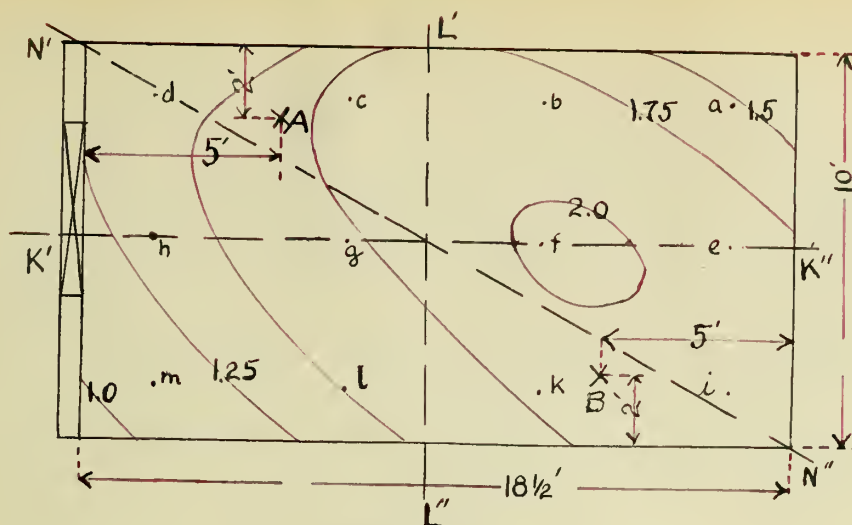


Fig. 19a

Indirect lighting distribution for Room No. 5

• a) Points at which illumination was calculated

X A Lamp clusters (2-100 watt lamps each)

Scale 1" = 5'

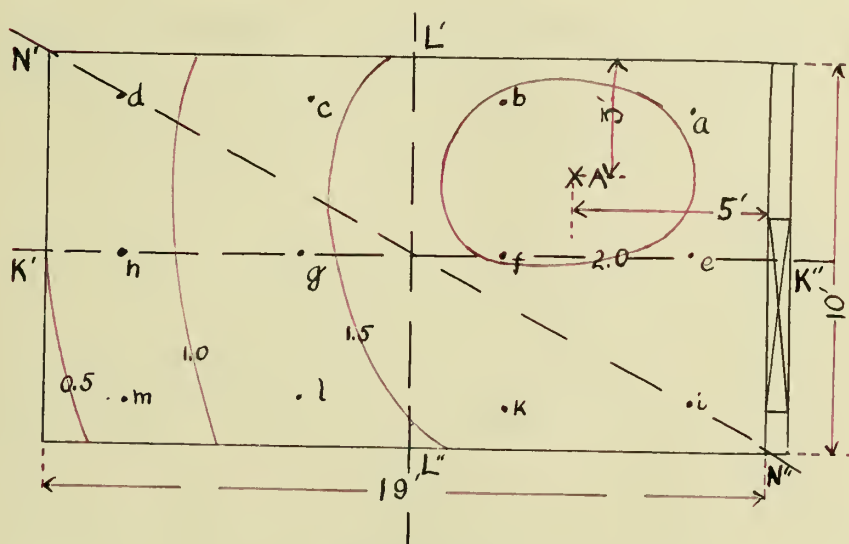


Fig. 20a

Indirect lighting distribution for Room No. 6

• a) Points at which illumination was calculated

X A Lamp clusters (2-100 watt lamps each)

Scale 1" = 5'

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3
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Foot Candles

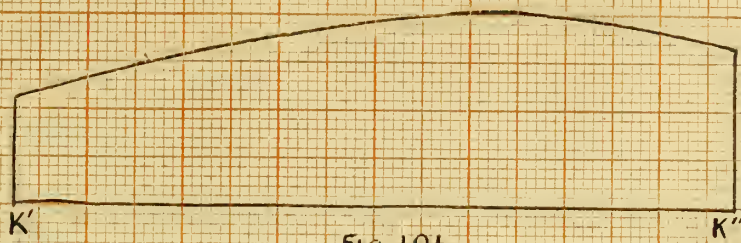


Fig 19b

Distribution of light along line K'K'' of Fig 19a
Horizontal Scale 1"=5'

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1
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Foot Candles

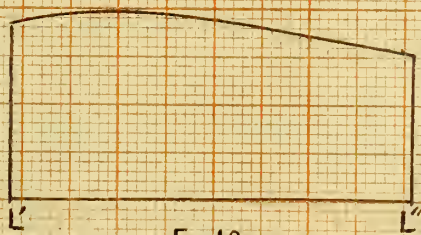


Fig 19c

Distribution of light along line L'L'' of Fig 19a.

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Foot Candles

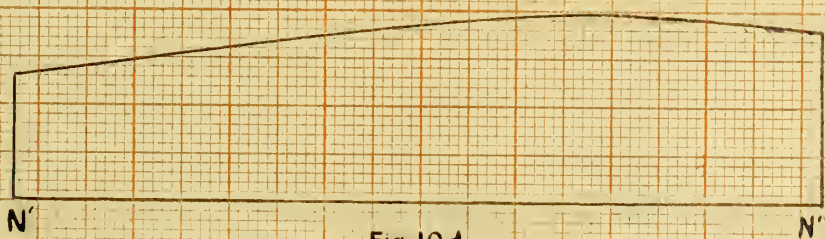


Fig 19d

Distribution of light along line N'N'' of Fig 19a

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Court of Sessions

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Foot Candles



Fig 20b

Distribution of light along line K'K'' of Fig 20a
Horizontal Scale 1"=5'

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1
0
Foot Candles

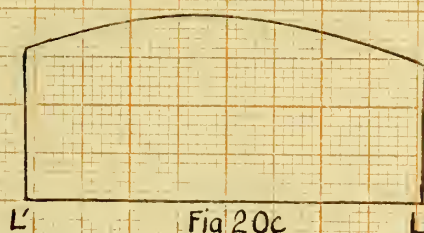


Fig 20c

Distribution of light along line L'L'' Fig 20a

3
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1
0
Foot Candles

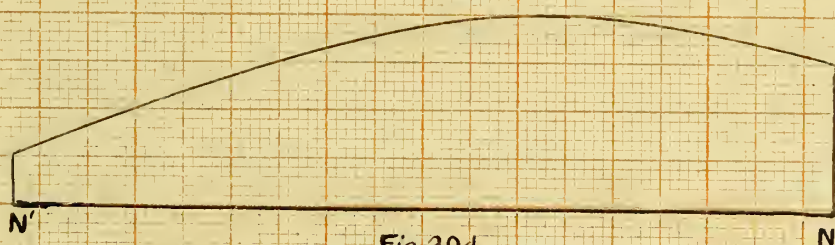


Fig. 20d

Distribution of light along line N'N'' of Fig 20a

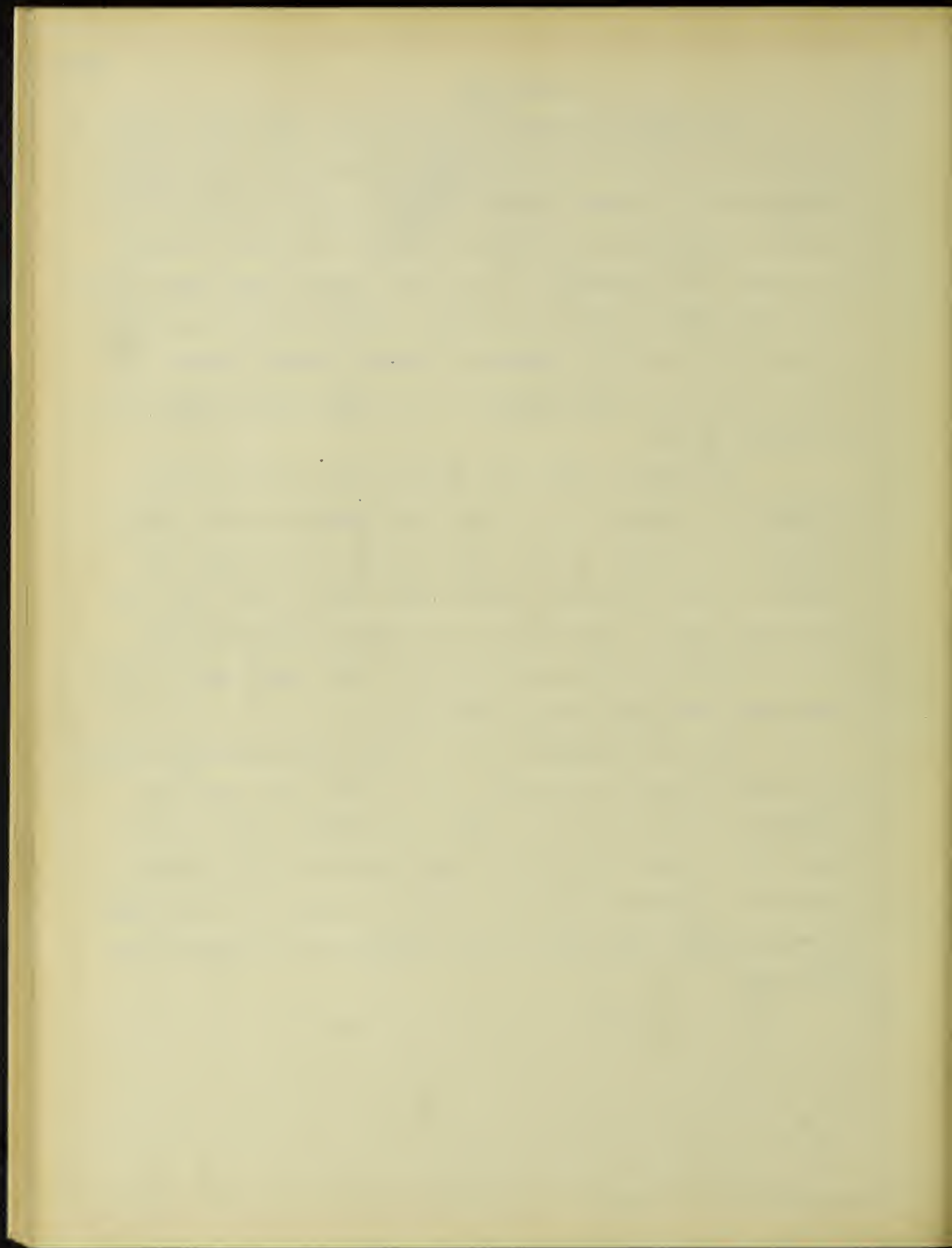
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CONCLUSION.

By comparing figures 8b, and 8c, with 15b, 15c, and 15d, figures 9b, 9c, and 9d, with 16b, 16c, and 16d, etc., it is evident that the indirect system of lighting gives a somewhat more uniform distribution. In addition to this as none of the lamps are visible it is impossible to blind the eyes by the glare of the direct rays always present in a direct system. The indirect system is also noticeable by the absence of sharply defined shadows. In fact in most of the rooms studied it was almost impossible to find any shadows at all.

By studying table 18 it will be seen that the power consumption is greater in the case of the indirect system than in the case of the direct system. Also the cost of the globes and fixtures is less for several reasons. The first is that there are more globes used in the indirect system than in the direct one. While the second is that the fixtures for that system costs considerable more than those for the direct one.

Summing everything up it is evident that the direct system is the less expensive of the two, both in first cost and power consumption; while on the other hand the indirect system gives a light which is much better on the eyes and which is much better distributed throughout the room. Thus both systems have advantages and disadvantages and should be used according to the surrounding conditions.



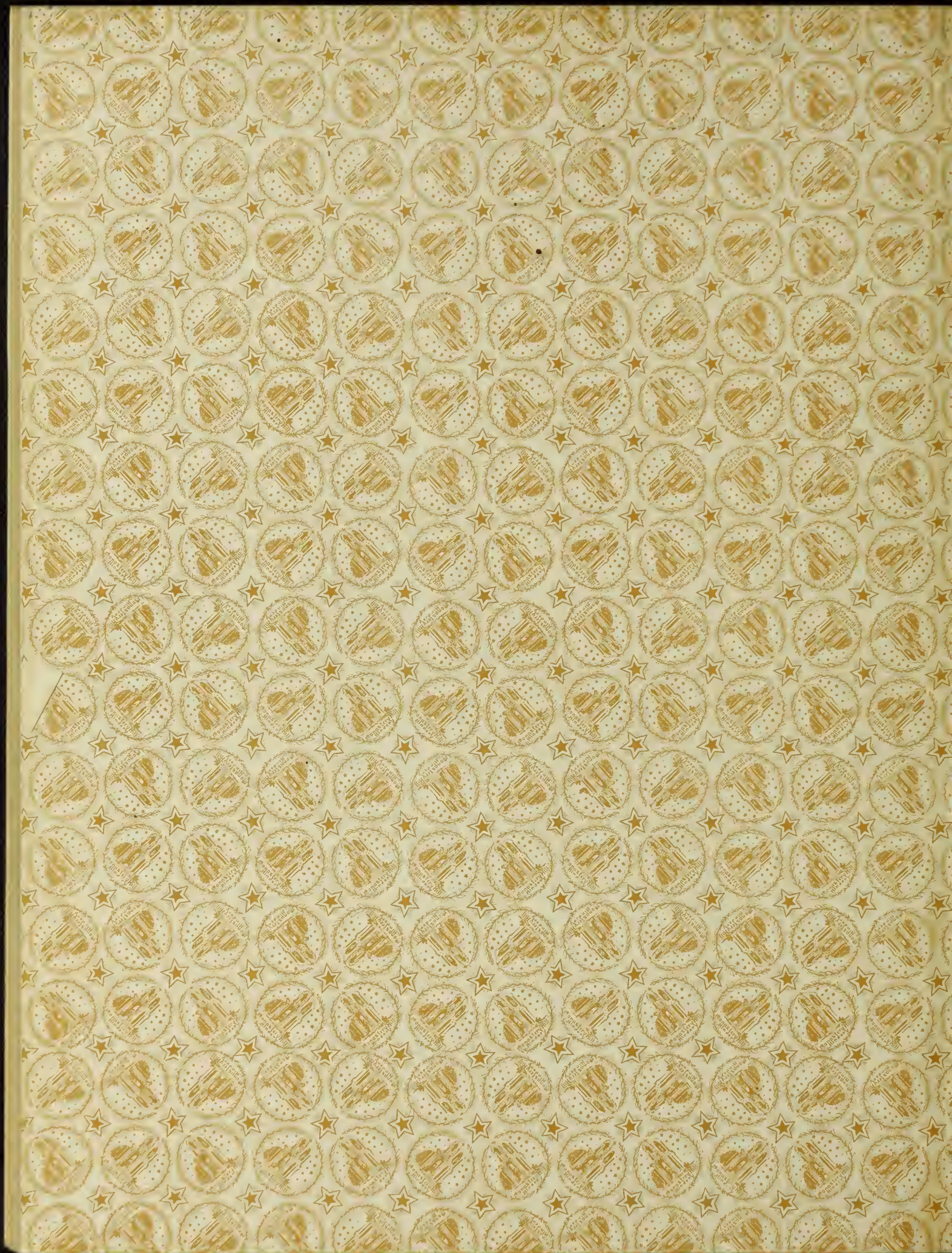
Comparison of costs of installation and amount
of power used in both systems

Direct lighting.

Room	Cost of lamps	Cost of reflectors	Cost of fixtures	Total cost	Watts consumed
1	\$5.40	\$8.40	\$40.00	\$53.80	400
2	\$5.00	\$7.80	\$50.00	\$62.80	300
3	\$6.00	\$9.36	\$60.00	\$75.36	360
4	\$12.00	\$18.72	\$75.00	\$95.72	1200
5	\$4.00	\$6.24	\$25.00	\$35.24	240
6	\$3.90	\$7.86	\$11.00	\$18.76	240

Indirect lighting.

Room	Cost of lamps	Cost of fixtures and reflectors	Total cost	Watts consumed
1	\$10.80	\$112.00	\$122.80	800
2	\$5.40	\$56.00	\$61.40	400
3	\$13.50	\$140.00	\$153.50	1000
4	\$16.20	\$196.00	\$212.20	1200
5	\$5.40	\$56.0	\$61.40	400
6	\$2.70	\$28.00	\$30.70	200





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